A Review on Air Quality Parameters for Ambient Pollution Management Framework

S. Sivakumar¹; Dr.V. Ramya²

¹Department of Computer Science and Engineering, Annamalai University, Annamalai Nagar, India.
²Department of Computer Science and Engineering, Annamalai University, Annamalai Nagar, India.
¹shivasigamani@gmail.com
²auembeddedsystem@gmail.com

Abstract
Pollution is the addition of perilous substances in to the environment that creates harmful atmosphere to human and other living creatures. Pollutants are components of solids, liquids or gases specifically emitted beyond the normal threshold level of concentrations that affects the atmosphere’s quality to a considerable extent. PM is one of the common air pollutants which is a combination of suspended solid and liquid particles in the air. PM₂.₅ pollution is becoming a severe problem due to automation of industries and more energy consumption. Because of this, the people will be affected by breathing issues leading to in heating, ventilation, and air conditioning (HVAC) due to the requirement of air cleansing. This paper assesses and evaluates the foundations of indoor and outdoor PM₂.₅ and the effect of PM₂.₅ pollution on surrounding prominence, occupational health and residents conduct. PM₂.₅ mainly creates heart disease, stroke, chronic obstructive pulmonary disease, lung cancer and other main health hazards. Inhaling SO₂ induces irritation to the nose, eyes, throat and lungs. When someone inhales NO₂, the gas rapidly dissolves into the blood stream and hits the brain within seconds. Low amounts of O₃ can cause chest pain, coughing and shortness of breath and throat infection. Further studies will forward us to a broad movement for the impact of PM₂.₅ towards health issues.

Key-words: Air Pollution, Indoor, Outdoor, PM₂.₅, PM₁₀, Sulfur Dioxide, Nitrogen Oxides.

1. Introduction

With reference to the air quality index report given by World Health Organization (WHO), air pollution is causing a huge damage to several developing nations and ambient air pollution (AAP) outburst with 4 million dying globally in 2012 and nearly 87 per cent about 0.68 million of these deaths occurs under the category of countries having low-and average economics [1]. Western Pacific and South East Asian countries account with 1.1 million and 0.79 million of death cases registered
under air pollution. Two large countries that contribute a huge proportion to statistical data as well as death rates are China and India [2,1]. In Europe, US, the Western Pacific and the Eastern Mediterranean account for nearly 0.38 million [1]. Since India is inclined towards faster urbanisation, the condition of air pollution will get worsened. Smudgy environment creates an adverse impact in human eyesight. Figure 1 shows a comparison of PM$_{2.5}$ and PM$_{10}$ sizes against with beach sand and human hair (with diameter of $\mu$m). A specialised cognitive area dealing with the framing, perceiving and assessing the various events happening to the human brain and body with respect to their residential environment is referred as Subjective Well-Being (SWB)[3]. The SWB evaluation is in preference to individual’s favourable criteria than the external needs. A conventional technique to examine the air pollution effects is the survey instrument based on SWB and it is been broadly utilized by both sociologists and economists. SWB is presumably included by policy makers to plan and assess the impacts of policies. The Asian nation of Bhutan serves as a perfect instance to explain the above mentioned factor of SWB. National happiness index is being adopted by several nations [2,3,4]. Due to this, several psychophysical methods are integrated in resolving the various problems associated with environment that includes landscape enchantments and necessary visual air quality needs. But the psychophysical procedure is not introduced in evaluating the impact of pollution on SWB.

![Fig. 1 - Size comparison of PM$_{2.5}$ and PM$_{10}$](image)

**A. Atmospheric climate condition**

In India, for a prolonged period of time, contaminants including PM$_{10}$ and PM$_{2.5}$ serve as the most prevalent pollutants in creating hazy weather patterns. PM$_{2.5}$ was the chief polluting particle of particulate matter and contributes for 66.8% of the highly contaminated days[5]. It turns to be more
toxic and dangerous component entering into the human body due to its comparative smaller size, wider surface area and easy portability[6,7]. PM$_{2.5}$ has a major role in deciding the atmospheric climate condition as it is suspended in the environment for a prolong period and moves a huge distance. Also it induces higher impact on human[8].

B. Chemical components of PM

In US, fixed monitoring stations under the control of government agencies are used to calculate the chemical components of PM. There are two monitoring networks namely the U.S. EPA Chemical Speciation Network (CSN) and the US-sponsored Interagency Monitoring of Safe Visual Environment (IMPROVE) to measure chemical components of PM [9,10,11]. Nearly 250 PM part monitoring stations, with an average of 3 monitors for every urban area, compared to 2,000 PM$_{2.5}$ monitors across the country. A Chemical Species Network to measure and assess twenty-six PM chemical components is implemented by the Environmental Protection Department in Hong Kong. Six general monitoring stations and one roadside monitoring station are distributed throughout the region. Samples were collected every six days. Estimating the spatial and temporal variability is quite difficult with small number of monitors. PM components generally include nitrate (NO$_3^-$), sulphate (SO$_4^{2-}$), aluminium (Al), calcium (Ca), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), selenium (Se) and zinc(Zn)[12].

C. Predicting the mortality related to air pollution

The air pollutants have a direct impact in respiratory and cardiovascular systems leading to increased airway reactivity, pulmonary inflammation [13,14]. It is also inter related with increased danger of death and morbidity [15,16]. All of these results intimate that air pollution is a threat to public health, specifically in mega cities [17]. Climatic conditions have an impact on concentrations of air pollutants by changing their emissions, aerosol photochemistry, transport and disposal. The temperature is directly proportional to O$_3$ concentrations due to the speeding up of photochemical reactions and higher biogenic volatile organic compound (VOC) emissions. As a result, given that climate change could get modified in the future, then there may be a growing interest in studying the way of air pollutants reaction with climate changes. Increased concentrations of air contaminants were expected by most, with high variability across regions. The Intergovernmental Panel on Climate Change (IPCC) concluded that climate change would modify a range of chemicals and processes that
regulate air quality, and that net effects differ from region to region probably (IPCC, 2007). As air pollution levels tend to be up in the future[18,19], there is increasing check about its consequent effect on public health[20]. Two of them were released in 2008 and presented only a result overview of the studies. Several studies are also conducted due to the progress in climate-air quality prediction model systems, that result in exploring more issues. Another study is centred around the methods in measuring the way of future climate change and impact in air pollution-related health effects [21], even though the results of these researches are not analysed and summarised completely. Hence, in order to fill these information gaps and make recommendations, we are quantifying the mortality prediction studies with respect to PM$_{2.5}$ and O$_3$ since the two air contaminants were the most explored. Also we have closely studied the various uncertainties in predicting the mortality related to air pollution.

2. Pollutants

There is a strong linkage between pollution and environmental change. Earth’s quality can be disrupted by the changes in climate [22]. The various pollutants such as methane, carbon, aerosols and tropospheric(ground level) ozone influence the sunlight. As a consequence, the Earth's temperature is rising and ice, icebergs and glaciers are melting and leads to frequent occurrence of natural climatic disasters[23]. corona (COViD19) virus from the china to entire world, as outbreaks of the disease were reported in all over the world[24] and very severe in India [25].Figure 2. typic different disease ratio from the house hold activates.

Fig 2. Indoor Air pollution disease ratio
A. Air pollutants

World Health Organisation has identified the major air pollutants as particulate pollution, carbon monoxide, Sulfur oxides and nitrogen oxides. Air pollution, such as groundwater, soil, and air, may have a drastic impact on all aspects of the ecosystem. In addition, it is a significant hazard to living creatures. Air pollution causes a noteworthy ecological imbalance through acid rain, environmental warming, greenhouse effects and frequent climate changes [26]. Our focus is primarily on these types of pollutants, as these are connected to more widespread and serious human health and environmental problems.

B. Particulate matter and Health

Studies of short-term acute and chronic PM exposure have shown an association between PM and SWB. As a result of chemical reactions between various contaminants, PM is commonly produced in the atmosphere. Particle penetration depends on its size [26]. The term particles are described by the United States Environmental Protection Agency [27] as PM. Particulate matter pollution involves particles with a diameter of 10 micrometres (μm) or smaller called PM₁₀ and extremely fine particles with a diameter of 2.5 micrometres (μm) and smaller in general. Particulate matter contains tiny droplets of liquid or solids that can be inhaled and cause severe health effects. After inhalation, particles smaller than 10 μm in diameter PM₁₀ can invade the lungs and even enter the bloodstream [28]. Different epidemiological studies have been carried out on the health effects of PM [28]. There was a favourable correlation between both short-term and long-term exposure to PM₂·₅ and acute nasopharyngitis [29]. Furthermore, long-term exposure to PM has been associated with cardiovascular disease and infant mortality for years. Such studies are focused on PM₂·₅ in the study area or suburban area, monitors are limited due to the lack of spatially resolved daily PM₂·₅ concentration data and it is not reflective of the entire population in this way. As PM₂·₅ levels differ spatially, an exposure error (Berkson error) appears to be created after a recent epidemiological analysis by the Department of Environmental Health at Harvard School of Public Health (Boston, MA) [30] and the strong relative magnitude of the short and long term effects is not yet fully elucidated. To determine short- and long-term human exposure, the team developed a PM₂·₅ exposure model based on remote sensing data. This model allows for short-term spatial resolution, as well as the estimation of long-term effects across the population. Respiratory disorders and weakening of the immune system are also reported as long-term chronic effects [31]. It should be noted that individuals
with asthma, influenza, diabetes, respiratory and cardiovascular conditions are particularly susceptible and resistant to the effects of Particulate Matter. Different respiratory system diseases are closely correlated with PM$_{2.5}$ accompanied by PM$_{10}$[32]. As their size allows interior spaces to be pierced by them [33]. Gas contaminants includes Smog, Soot, Cigarette Smoke, Oil Smoke, Fly Ash, and Cement Dust, and Particulate Matters are classified into 4 major groups according to form and scale [34]. Microorganisms (bacteria, viruses, fungi, mould and bacterial spores), pet allergens, house dust and allergens, pollen, are biological pollutants. Dust forms include Suspended Dust of the Atmosphere, Settling Dust, and Heavy Dust. Finally, because of their tiny measurements, PM$_{10}$ and PM$_{2.5}$ particles' half-life in the atmosphere is extended; this enables their long-lasting suspension in the atmosphere and even their move and spread to distant destinations where people and the environment can be exposed to the same magnitude [22]. In watery environments, they are able to alter the nutrient balance, destroy forests and crops and acidify water sources. As reported, PM$_{2.5}$ causes more serious health effects due to its small size. The key cause of the 'haze' formation in various metropolises [21] [22] is these aforementioned fine particles.

C. Environmental impact by Ozone

Ozone (O$_3$) is a gas formed under high-voltage electric discharge from oxygen[33]. It is a potent oxidant that is 52% stronger than chlorine. It occurs in the stratosphere, but it may also occur in the troposphere following chain reactions of photochemical smog [34]. With air masses, ozone may pass to distant areas from its initial source [35]. In comparison to the higher amounts in urban areas, it is alarming that ozone levels over urban areas are low, posing a danger to cultures, forests and vegetation[36] as it decreases carbon assimilation [37]. Ozone decreases growth and yield and affects the microflora of plants due to its antimicrobial potential [38][39]. To this degree, ozone affects the microflora of other natural habitats [40,41] and changes the composition of animal species [42]. In epidermal keratinocytes, ozone increases harmful DNA and contributes to impaired cell function [43]. Ground level ozone (GLO) is produced from a chemical reaction released from natural sources and/or after anthropogenic activity between nitrogen oxides and VOCs. Usually, ozone uptake occurs through inhalation. The upper layers of the skin and tear ducts are damaged by ozone [44]. A analysis of short-term exposure of mice to high ozone levels showed the development of malondialdehyde in the upper skin (epidermis) but also vitamin C and E depletion. Ozone levels are not likely to interfere with the role and integrity of the skin barrier for predispose to skin disease [45]. Inhaled ozone has the ability to penetrate deeply into the lungs due to the poor solubility of ozone in
In urban areas worldwide, ozone-induced toxic effects are documented to cause biochemical, morphological, functional and immunological disorders [47,48].

**D. Nitrogen oxide (NO$_2$) impact in the atmosphere**

The reddish-brown gas with strong oxidant properties is nitrogen dioxide (NO$_2$). Compared to concentrations in urban regions, natural background concentrations are low. Annual mean concentrations of NO$_2$ range from 20 to 90μg/m$^3$ in urban areas around the world. The highest average amount up to 1000μg/m$^3$. NO$_2$ is emitted from vehicle motor engines, nitrogen oxide is a traffic-related pollutant [49]. It is an irritant of the respiratory system when, when inhaled at high levels, it penetrates deep into the lung, causing respiratory disorders, coughing, wheezing, bronchospasm and even pulmonary edema. In humans, concentrations above 0.2 pm tend to cause these adverse effects, whereas concentrations above 2.0 ppm affect T-lymphocytes, particularly the CD8+ cells and NK cells that generate our immune response.[50]. High levels of nitrogen dioxide are detrimental to crops and vegetation, as a decrease in crop yield and efficiency of plant growth is observed. In addition, NO$_2$ can reduce visibility and fabric discoloration [50]. It is observed that NO$_2$ is emitted in increased levels by the devices used in combustion at homes in the order of 200 which affects the air path and lungs analysed in various studies[51, 52] Usage of gasoline-powered ice resurfacing machines [53] also induces NO$_2$ exposure. Several proofs from animal toxicology experiments, controlled and epidemiological studies were reviewed by the World Health Organization [51] Exposure in controlled conditions were analysed by[53]. Indoor and outdoor exposure in accordance with epidemiological studies were concentrated by [54].

**E. NO$_2$ impact in different location of the globe**

The reactivity of bronchi is induced by NO$_2$ and it is evident from the response of normal and asthmatic patients subjected to pharma-ecological broncho constrictor agents at a non-affecting level of pulmonary functions in the absence of a broncho constrictor. In contrast to this, few cases exhibit increased receptiveness to broncho constrictors at lower NO$_2$ levels of 376 to 565μg/m$^3$; A consistency in validating the health consequences of the increased receptiveness to broncho constrictors is still infeasible[51]. The receptiveness is increased to natural allergens also in the same range. The consequences of monotonous exposures of those kinds of individuals, or the influence of single exposures on more serious asthmatics, are not analysable [51]. It is suggested from the meta-
analysis conducted for school going children that the cooking gas exposure have 30μg/m³ induces a minute but considerable 20% increase of gas for cooking with an equivalent exposure was associated with a slight, but significant, in the generality of disorders in respiration [55]. And also, various analyses prove that cooking gas has showed constancy in respiratory problems and aggravating the functioning of lungs with respect to asthma affected adults [58-60]. NO₂ in the order of 100μg/m³ has a minute effect in airpath reactivity of asthma persons due to inspired allergens by three studies [64-66]. In Sweden, asthma is worsened due to the daily changes in NO₂[67]. Infant studies failed to prove the above-mentioned results. In contrary to this, the European Community Health Survey has shown the linkage between females involved in cooking and the lung disorders never had constancy [61]. In Australia, there is an association between children and their exposure to NO₂ had incidents of having cold, soreness in throats, asthma, wheezing and school absenteeism [62,63]. It is also found that the children with prolonged exposures to ambient NO₂ suffer with high levels of respiratory problems and lungs dis functioning [68] and also chronic cough, bronchitis and conjunctivitis [73,74]. Various study works have found about the exacerbation of chronic bronchitis and emphysema ΠΜ [68-70].

F. Evidence for health impact

Prolonged exposure of children with an annual mean value of 50 to 75μg/m³ or higher are vulnerable to respiratory disorders whereas there are no sufficient results to show the effect levels in adults [51]. As per the panel cohorts report, the relativity of outdoor NO₂ to respiratory problems and lung functioning decreases in children. In single pollutant analysis, increased cough and lower symptoms of respiratory problems were found by a study [61]. There are certain studies which reveal about connectivity restricted to lung functioning alone [76-79]. There are some linkage between ambient NO₂ and the hours having high-peak and the cardio vascular mortality rate [30, 32, 40; 85-87]; Some works prove that pollutants like SPM and CO shown greater connections than NO₂. In a nutshell, copious evidences are not present to denote the relativity of NO₂ to health hazards from epidemiological studies. It is concluded that NO₂ contributes to a considerable extent in affecting the health with the help of existing evidences.

G. Carbon monoxide (CO)

Improper combustion of carbonaceous components produces a colourless, odourless, tasteless and insoluble gas which is termed as carbon monoxide that gets the large proportion from internal
combustion engine exhausts from petrol engine vehicles. CO emissions influence greatly in climate changes and global warming like occurrence of storms and increasing the soil and water temperature [78]. It leads to dizziness, Headache, nausea, fatigue, vomiting, and gradual loss of consciousness. The affinity towards carbon monoxide is greater than that of oxygen in haemoglobin and results in severe poisoning in blood veins for people having prolonged exposure to CO. Due to the less affinity towards oxygen, carbon monoxide is mixed with the haemoglobin successfully and creates diseases such as ischemia, hypoxia and cardio vascular disorders. In laboratories and field findings had increased growth in plants [79]. The vehicle density has a major role in deciding the concentrations of CO. The maximum occurrence of concentration falls between the morning and evening rush hours in several cities. An eight hour concentration of CO in European cities vary between 1 and 20μg/m³[80-81] and this is approximately 8 times higher than those measurements in ambient air [82]. Car models, traffic patterns, ventilations, car maintenance and climate also influence CO levels in car. [83-84]. High peak hour of CO exposures in urban areas is undervalued by monitoring stations. The presence of improper ventilation in places like tunnels and parking areas have the higher vulnerability to CO emission[85,86]. Severe poisoning has been observed in even icy regions [87, 88]. The CO concentrations can be raised to 50μg/m³ from environmental tobacco smoke in indoor environments . CO spreads fast inside the lungs through alveolar, capillary and placental membranes as the lungs are the most suited route for CO intake. Carboxy haemoglobin (COHb) is formed after inhaled CO around 80 to 90% combines with haemoglobin thereby decreasing the o2 carrying capability of blood and distorts the oxygen release from blood. After the onset of exposure, the concentration of COHb rapidly elevates and within 6 to 8 hours, the concentrations of CO in outdoor air and alveolar breath remain equal. Coburn-Foster-Kane exponential equation is used to denote the intake and elimination of CO [89]. Benignus has shown about the devastated behavioural patterns of CO exposure like impairment of eyes and vision when the COHb levels are beyond 18% [90]. During pregnancy, Maternal COHb levels are normally about 20%higher in pregnancy period than the non-pregnant individual values; There are high rate of vulnerabilities imposed by CO to the pregnant mother, the fetes, and the infant . Endogenous production of CO results in COHb levels of 0.4% to 0.7% in healthy individuals. And this elevated endogenous production causes increased maternal COHb levels of 0.7% to 2.5% around 0.5% to 1.5% for non-smoking general individuals. These type of persons falls under the occupation categories of being an auto-mobile driver, policeman, firemen, traffic warden, garage and tunnel worker have possess the chances of long term COHb levels of 5%, and chain smokers having of 10% [90] . Individuals with heavy work outs can have the ability to increase the COHb levels by up to 10%to 20% when exposed to indoor environments.
H. Sulfur dioxide

Sulfur dioxide is a toxic gas that is emitted primarily from the use or manufacturing activities of fossil fuels. SO\textsubscript{2} ’s annual norm is 0.03 ppm [92]. It affects plants, animals and humans. Susceptible individuals, such as those with lung disease, are at greater risk of harm to older individuals and children. In most cities, the major health effects of Sulfur dioxide are concerned with irritations in respiratory system, bronchitis, production of mucus and bronchospasm as it can penetrate more into lungs due to its sensory irritant nature. Inside the lungs, it gets changed into bisulfide and leads to constriction of bronchus by interacting with receptors. It also extends in creating redness of skin, damaging the lachrymal glands and opacity of cornea and ultimately putting the cardiovascular system in high risk [51]. Sulfur dioxide emissions tend to be associated with acidification and acid rain [93]. SO\textsubscript{2} is a toxic, colorless and water soluble gas produced from both natural and anthropogenic activities like volcanoes and usage of fossil fuels containing Sulfur in domestic cooking, heating, generation of power respectively. The diurnal and annual mean concentrations of SO\textsubscript{2} are below 100μg/m\textsuperscript{3} and 500μg/m\textsuperscript{3} in several cities of America and Europe. The US based Committee reviewed about the perilous nature of SO\textsubscript{2} in 1996 from the American Thoracic Society[51]. Europe has updated and revised the guidelines through the toxicological and epidemiological studies on the health effects of SO\textsubscript{2} [93]. A research work stated about Sulfur dioxide’s toxicology and health effects induced by SO\textsubscript{2} emitted from traffic[94]. The severe effects of SO\textsubscript{2} rise from controlled chamber observation with volunteers exposed to SO\textsubscript{2} concentrations above 500μg/m\textsuperscript{3} for periods of few minutes to hours[51]. From the experiments it was observed that healthy persons have exhibited upper respiratory symptoms and asthmatics and respiratory hyper receptiveness persons have shown acute responses immediately after the inhalation of SO\textsubscript{2}. It causes reductions in forced vital capacity (FVC) and increases airpath resistance with symptoms of breath shortness or wheezing in balanced individuals. Exercise is a factor in increasing the mass of inhaled air since it permits the penetration of SO\textsubscript{2} in a deeper mode into the respiratory path. A review of Mumbai city of India exhibited SO\textsubscript{2} effects in a daily basis mortality resulting from cardiorespiratory diseases. The data were not sufficient in classifying the effects of SO\textsubscript{2} are separated or combined with SPM I2AI. Athens and France had conducted a time-series studies that denote SO\textsubscript{2} induces independent severe health effects in both genders of people on daily mortality having age group of 65yrs and above [96]. At winter season, a small amount of correlativity was observed by the study conducted by Poland Pollution control board with mortality of male at the age of 65 having exposure to PM\textsubscript{10} and SO\textsubscript{2}. PM\textsubscript{20} induced no causes on mortality even after adjusting the levels of SO\textsubscript{2}. An
estimation was given by the authors that incrementing the SO$_2$ concentration for about 100μg/m$^3$, resulted in an increment of 19% and 10% of fatal respiratory diseases and cardio vascular diseases respectively was estimated by the authors. Delhi has conducted a study [96] and inferred about the extreme serious linkage between Sulfur dioxide’s logarithmic levels and the fatality rate per day. Diseases such as chronic bronchitis, chronic obstructive pulmonary disease, and colour pulmonale have shown higher fatality rates. It is unfortunate in using the results and inferences of all these research works in estimating the dose-response relations. A considerable amount of increase was observed in both respiratory and circulatory system disorders with increased exposure to SO$_2$. There are some studies which reviewed about the influence of other components in the mixture of air pollutants and meteorological compounds [96]. But multi pollutant mix is not used in the APHEA studies. A valid establishment is not presented in relating the SO$_2$ and other pollutants for deciding the mortality. In Netherlands, a multi-variate review was conducted that concludes in a way of relative lower concentrations of SO$_2$ concentrations did not have short term-based effects on mortality [98]. An increment in SO$_2$ was strongly connected with morbidity of hospital admissions due to cardio vascular and respiratory disorders. There were no sufficient results given by the studies within the APHEA work [51]. Lung disorders with long range of sensitivity was demonstrated for both normal adults and adults with asthma (for instance, Nowak et al. [93]). Asthma affected people are the most vulnerable group in the community.

I. Lead

It is a heavy metal emitted from petrol motor engines, batteries, radiators, waste incinerators and waste waters and sources of lead include metals, ores, aircrafts with piston engine models. It is used in various industrial plants [98]. The serious threat to all living creatures is poising from lead because of its detrimental effects specifically widespread in developing nations. The process of inhaling, ingesting and dermal absorbing are the sources through which lead is exposed into human. The inhalation of lead gets gathered in blood, liver, lungs, tissues, bones, nerves and reproductive parts. This results in passing of lead into the unencumbered placenta in the form of trans-placental transport mode. Consequently, the poisonous effects gets aggravated more for the younger foetus such as damaging the nervous system, brain swelling. Even a minute quantity of lead is a kind of toxicant affecting nervous system resulting in disabilities with learning, perception, memory and mental impairments, hyper sensitivity in new born and young children[100]. Similarly, adults also suffered from concentration and memory loss, muscular pain etc. [100]. Lead’s poisonous effects are
not limited to humans, but also extends in damaging the crops and inducing nerve related problems in animals especially vertebrates [101].

J. Dioxins

Natural disasters like volcanic outbursts and forest fires are some sources of dioxins and man-made industries also play a role in emitting dioxins. It is evident that consumption of fossil fuels reserves a substantial part in contaminating the air. And this kind of contamination may be due to man-made activities like agriculture, transport and industrial processes or some of the natural causes also. Sea food like fish, shellfish and eatables like meat, dairy items and animal tissues are components getting accumulated with lead [102]. Shortened and prolonged exposure to lead results in occurrence of lesions and dark spots over skin and growth-related problems. Immune underdevelopment and impairments in endocrine, reproductive and nervous systems respectively. Its elevated effects are tumour and infertility issues.[102]. It is interested in observing that European Air Quality Directive standards are far better to Who air quality guidelines[103].

3. Sources of pollution PM$_{2.5}$

Human induced and natural sources play a key role in discharging PM into the environment by two modes. The former being the direct release into the atmosphere and latter being the transfer of gaseous precursors such as Sulfur dioxide , nitrogen oxides, ammonia and non-methane volatile organic compounds [104]. Human induced processes ranging from combustion of coal, heavy oil, lignite and biomass to industrial and agricultural activities are variable in nature. It also includes road-traffic surface degradation, and brake and tyre abrasion. The primary source of PM is the traffic from which the wear of vehicle components such as brakes and tyres and road dust are suspended . In addition to this, tyre and brake matter can contain metals like copper (Cu), antimony (Sb), lead (Pb ), cadmium (Cd), and zinc ( Zn) . Tyre abrasion induces the discharge of inorganic abrasive crustal material particles rich in silicone (Si), aluminium (Al), potassium ( K), sodium ( Na) and calcium ( Ca).In contrast, the volcanoes, dust storms, forest fires, living plants, and sea spray are the natural sources of PM following Figure 3. shows the different sources of pollution activate
A. PM$_{2.5}$ possibility of moving in air

Due to their minute sizes, these kind of particles remain in air for a prolonged period of time and have the possibility of moving to hundreds of kilometers. The changes in wind patterns and atmospheric stability decide the fractions of different PM concentrations and that can vary drastically from one day to the other (or even from hour to hour). It is common to find that PM concentrations in the indoor environment exceed the outdoor environment. Indoor activities such as cooking, pets, mooring, household goods manufacturing liquid aerosols (e.g., aerosol cans) and office equipment’s (e.g., printers and photocopiers) constitute a considerable amount of PM$^{106}$. The most important factors of exposure in households are fuel and stove types, cooking period and neighborhood smoke. Even candles and incense sticks emit PM at the range of 100 to 1,700μg/m$^3$. The several livelihood facilities possess indoor PM contamination compared to recognisable source activities$^{107}$. In India, average PM$_{10}$ concentrations of 128μg/m$^3$ were found in four hospitals in Delhi City. Concentrations of PM$_{10}$ were found to be 77.0 ± 29.9, 74.0 ± 23.6, 93.5 ± 9.47, and 66.7 ± 15.8μg/m$^3$ respectively$^{[108]}$ in indoor environments like children's care facilities, medical facilities, postnatal care centres, and elementary schools. Mean concentrations of PM$_{10}$ in elementary school were present in the range 66.7 to 77.9μg/m$^3$.

B. Sources of Indoor PM$_{2.5}$

Sources of indoor PM$_{2.5}$ is represented in Figure 2. Indoor PM$_{2.5}$ pollution sources are typically produced transiently and intermittently, resulting in wide variations in indoor particulate
There are several different forms of indoor PM$_{2.5}$ sources, primarily from fuel combustion, human activities, equipment operation, cleaning and cooking. Indoor combustion of fuels such as coal, natural gas, alcohol, and mosquito coils which lead to a rapid increase in indoor PM$_{2.5}$ concentration\[110\]. have shown that burning a mosquito coil ring is capable of delivering 626μg/m$^3$ of PM$_{2.5}$ – 8.3 times the concentration limit permitted for the indoor setting\[111\] concluded that the concentration of PM$_{2.5}$ in households using coal for cooking was substantially higher than in households using gas or electricity, and that if coal is converted to gas or electricity, the concentration of PM$_{2.5}$ in the kitchen could be reduced by 40–70%\[112\] suggested that human activities, such as walking, dressing and washing, could result in an increase of 33 per cent indoor PM$_{2.5}$\[113\] performed dry-weeping, wet-weeping and air-drying tests in the office.

**C. Human made sources of PM$_{2.5}$**

PM$_{2.5}$ emissions from road vehicles are a significant source India. As a result, PM$_{2.5}$ (and population exposure) levels along roadsides are often much higher than those in background areas. Industrial pollution may also be significant in some areas, such as the use of non-smoking fuels for heating purposes and other domestic sources of smoke, such as bonfires. Under certain weather conditions, air polluted with PM$_{2.5}$ from the mainland could circulate throughout the United Kingdom – a condition known as the long-range transport of air pollution. Long-range transport, along with pollution from local sources, can contribute to short-term episodes of high pollution that could have an effect on the health of those vulnerable to high pollution. In addition to these direct (i.e. primary) emissions of particulate matter, PM$_{2.5}$ can also be produced from chemical reactions of gases such as Sulfur dioxide (SO$_2$) and nitrogen oxides (NOx: nitric oxide, NO plus). Consequently, steps to minimize the emissions of these precursor gases are also helpful in decreasing the overall amount of PM$_{2.5}$\[114\].

**D. Outdoor sources of PM$_{2.5}$**

Combustion of fossil fuels Home Heating Electricity generation Motor vehicles Manufacturing processes Agricultural processes Waste incineration Natural processes Thunderstorms Volcanoes Manufacturing or agricultural operations Disposal of industrial effluents and domestic residues Traffic Solid waste management Chemical accidents and spills Ozone(O3).
1. Nitrogen Oxides (NOx)
2. Carbon Monoxide (CO)
3. Sulfur Dioxide (SO₂)
4. Particulate Matter (PM₁₀ and PM₂.₅)

These imperceptible urban contaminants can be defended by adopting some effortless procedures. For instance, when a grey-sky day is encountered, it is necessary to:

- Reduce the outdoor activity;
- Sticking to air quality measures
- Wearing an appropriate pollutant mask blocking 95% or more of the particles

A big initiative towards protecting the air is to analyse the nature of air surrounding us and by periodical testing of air quality index in a respective station before moving outdoor.

4. Sources of pollution PM₂.₅

A. Health impact by PM₂.₅

A description of the health impacts examined in this part. A review research on PM₂.₅ in India, including health effects, was recently conducted by [115]. Four PM₂.₅ health effects studies in Delhi have been illustrated in this study and are summarised here. recorded substantial increases in overall mortality, cardiovascular mortality and respiratory mortality with a 10μg/m³ rise in PM₂.₅ concentrations between 2007 and 2008. In addition,[116] identified substantial associations between elevated PM₂.₅ levels and emergency room visits to cardiovascular disease incidents between 2004 and 2006[117].During this analysis, the average daily concentration of PM₂.₅ was 122μg/m³. The average increase was 0.69 percent and 1.32 percent respectively, which are still important. This study showed that adverse effects of lags ranging from 0 to 8 days were observed and were still important after control for variables such as time trend, seasonality, and meteorological influences. The Figure 4. shows different cardiology disease by the pollution in percentage.

B. Impact on human lung and respiratory diseases

PM₁₀ and PM₂.₅ possess small and minute inhalable particles that can easily enter the thoracic portion of human’s respiratory system. The health effects are due to short-term (hours, days) and long-term (months, years) exposure and include
i) Morbidity in respiratory and cardiovascular systems leading to exasperation in asthma and frequent admissions to hospitals.

ii) Cardiovascular, respiratory diseases and lung cancer showing high rates of mortality.

It is evident from the effects of short-term exposure to PM$_{10}$ on respiratory system, but for mortality, and specifically as a result of long-term exposure, PM$_{2.5}$ is a huge risk factor than the gross component of PM$_{10}$ (particles in the 2.5–10μg/m$^3$ range). It is calculated that all-cause daily mortality increases by 0.2–0.6 per cent per 10μg/m$^3$ of PM$_{10}$[130,122]. Long-term exposure to PM$_{2.5}$ is related to an improvement in the long-term risk of cardiopulmonary mortality by 6–13 per 10μg/m$^3$ of PM$_{2.5}$ [123-125]. In particular, people already with lung or heart disease, elderly adults and children are the most vulnerable groups. Exposure to PM causes problems in lung development for children resulting in reversible lung function deficits and improper growth of lungs and a deficit in lung functioning for a long term [126]. There is no evidence of a normal level of exposure or a threshold at which there are no severe health effects. Exposure is prevalent and voluntary in nature leading to create awareness about this health determinant.

Minute particles having sizes smaller than 10 micrometres in diameter impose the human health under risk by getting deeper in to the lungs and its passages, heart while others enter in to the blood stream. Therefore the size is directly connected to the capability of particles in creating dangerous effects in human. Various scientific studies have shown that a variety of health hazards are directly resulted from exposure to particle pollution such as:

- More fatality in lung and heart diseases
- Frequent mild heart attacks
- Uneven heartbeat
- Exasperated asthma
- Improper functioning of lungs

Repetitive respiratory symptoms like airways irritation, coughing or breathing difficulties People already with heart or lung problems, children and elderly people are prone more to get affected by particle emissions.
C. Environmental Effects of air pollution

Polluted air creates hazardous effects to both human and environment [127]. The most crucial impact of environment is the outpour of acid rain having harmful proportions of nitric and sulfuric acid. It can be either in wet form (rain, fog, snow) or in rain form (particles and gas) It can acidify the aquatic and soil environment and can affect trees and crops, as well as damage to constructions and external carvings, statues. Industries, nuclear plants, heavy vehicles create smaller particles which get distributed in air in the form of hazes. The atmosphere’s visibility is obscured during the occurrence of hazes. The presence of ozone at stratosphere shields the ultraviolet sunlight from harming the human whereas ground level ozone is detrimental in the form of a pollutant. Miserably, stratospheric ozone is being exhausted and destructed by chemicals, pesticides and aerosols from various types of industries and vehicles that causes disastrous consequences in human life [128] and crops[129] due to the thinning of ozone layer. The temperature of earth is stabilised by the greenhouse effect concept and Global climate change grows as a life threatening problem these years. This protection effect is destroyed by human induced activities by emitting huge volume of greenhouse gases. Global warming effects have the ruinous power over all living creatures, forests, biodiversity, agriculture and the water system. People living in poorly built buildings and houses in hot climate countries are most prone to risky life according to the report [130] when temperature rises. Sterility and pre mature birth problems have been reported. When the nutrient(nitrogenic) concentration elevates to a higher point, it induces the large volume of aquatic algae blooming which is termed as Eutrophication. It in turn puts fish and other aquatic species at risk. In accordance with Canada Acid Rain Program, it is evident that there is a serious concentration of contaminants with which the atmosphere can tolerate
to some extent without being destructed and is connected with the system’s capability to neutralise acidity. This load has been approximated at 20 kg /yr [131]. People inhabiting the cities are comparatively facing greater exposure to PM as per the Global Health Observatory (GHO) data in 2016[24]. And it is around 90% greater than air quality guidelines given by WHO. It sets the Air Quality Guideline which is the annual mean concentration of particulate matter (PM). The guideline for PM$_{2.5}$ does not exceed 10µg/m$^3$ annual mean or 25 µg/m$^3$ for 24 hours average and PM10 does not exceed 20 µg/m$^3$ annual mean or 50 µg/m$^3$ for 24 hours average. Starting from India (68µg/m$^3$), Bangladesh (58.6µg/m$^3$), Bhutan (35.4µg/m$^3$), Myanmar (34.6 µg/m$^3$), the Democratic Citizens of the Republic of Korea (31.0µg/m$^3$), Thailand (26.6µg/m$^3$), Timor-Leste (18.2µg/m$^3$), Indonesia (16.4µg/m$^3$) and Sri Lanka (15.1µg/m$^3$) with the exception of the Maldives (7.7µg/m$^3$) showed that the annual mean concentration of fine particulate matter in urban areas surpassed.

D. Airway system impact

The health effects of air pollution on the airway system (lower airways) include acute and chronic changes in pulmonary function, increased frequency and prevalence of respiratory symptoms, allergen sensitization of airways, and exacerbation of respiratory infections such as rhinitis, sinusitis, pneumonia, alveolitis, and legion disease. The key agents for these health effects are the combustion products SO$_2$, NO$_2$, SPM with a mean aerodynamic diameter of less than 10µg and lower, and CO. Fine SPM, formaldehyde and infectious organisms may also serve as important agents in addition to indoor air contaminants.

E. Efficient Strategies for Pollution Avoidance

Pollution in air can be reduced by using some efficient strategies in transport, urban planning, power generation and manufacturing:

- Industry related: smoke stacks can be reduced by using appropriate cleaning technologies; urban and agricultural waste should be managed properly including methane gas from waste sites as an alternative approach to incineration (for use as biogas);
- Electricity: Activities like cooking, heating and lighting should be managed using economical and renewable household energy solutions
- Transport: electricity should be made to generate in sustainable modes; systematizing rapid mass transit, mass walking and cycling networks. Initiating inter urban rail freight and
passenger transport; moving towards cleaner heavy-duty diesel vehicles, low-emission vehicles and fuels and low-Sulfur fuels;

- Urban planning: The buildings should be constructed in a way to enhance the energy efficiency and cities are to be made greener and compact

- Low-emission fuels and non-combustion renewable energy sources should be promoted for usage like solar, wind or hydro power; co-generation of heat and power; and distributed generation of energy like mini-grids and rooftop solar power generation.

- Urban and agricultural waste management: adopting different methodologies for reducing and separating, recycling and re-use or reprocessing of wastes; Promoting anaerobic waste digestion for biogas production which is a refined as well as feasible biological waste management approach; replacing the open solid waste incineration with low cost alternatives. Combustion methodologies with severe emission controls are mandatory for unavoidable incinerations.

5. Indoor PM$_{2.5}$ Control

PM$_{2.5}$ avoidsances strategies in indoor Figure 5 typic different solutions to overcome the pollution namely energy efficient power management, Solar based energy, Eco-friendly battery powered vehicles, intelligent waste management and smart agricultural activities.

A. Filters and Conditioner Recommendation

It becomes crucial to decrease the outcomes of PM$_{2.5}$ over the occupants health by regular monitoring of its indoor pollution level as short term elimination of PM$_{2.5}$ is impractical. Some research works have focussed on selecting a particular combination of air philtres, for instance, design of an a plan to reduce the PM$_{2.5}$ level in indoor [132]. A philtre efficiency test is conducted based on a particle size, counting system and a PM$_{2.5}$ weight filtration method for different air philtres with varying materials and particle removal efficiencies under the similar experimental factors. A preliminary standard is provided by the relativity between the above said two filtration efficiencies to select PM$_{2.5}$ air philtres specifically for air cooling and ventilation systems at indoor. The effectiveness with respect to filtration for varying categories of PM$_{2.5}$ philtres was examined by [133] and stated admissible philtre combination schemes depending on the pollution status of PM$_{2.5}$ in different places. Preliminary air conditioning systems are designed on a PM$_{2.5}$ concentration model.
for indoor is designed by [134] in accordance with the law of conservation of mass. The development in filtration and the flow rate of fresh air on indoor PM$_{2.5}$ is analysed with respect to primary, return and supply air sections. Since the split air conditioning systems are ductless systems, widely installed in most residential buildings for controlling the indoor environment in India. Evaporating and condensing units are separated from each other by indoor and outdoor heat exchangers respectively. Closing the doors and windows is the major step taken by the people of India in dealing with PM$_{2.5}$. Consequently, fresh air is not handled by air philtres and it’s the point where PM$_{2.5}$ cracks. Maintaining an indoor atmosphere safely inside the buildings with isolated AC exists as an unsolved problem in India.

Fig. 5 - Solution to different kind of pollutions

**B. New Material for PM$_{2.5}$ Air Filters**

New philtre products production is being worked by the researchers. Electro spun polyvinylidene fluoride (PVDF) doped with negative ion powders (NIPs) provide an efficiency of 99.9% in purification when it is embedded with highly efficient and lower resistance air purifying components [135]. A highly effective polyimide nanofiber air philtre is devised by [136] with high-thermal-stability polyimide nanofibers and its performance efficiency rates to 99.5% in eliminating the automotive exhaust at heavy temperatures. Polyether sulfone membrane is a reusable hollow fibre given by [137] which is highly permeable using single-jet wet-spinning technology. The capture capacity of PM$_{2.5}$ is higher in these above mentioned philtres and can be employed in Ac systems that eliminates the need of removing the PM$_{2.5}$ at indoor. It becomes impractical to implement this mode of philtres due to the heavy investment cost in the initial stage. Another mode of invention is that creating and adding the sensors to windows which permits the flow of air by reducing the costs of
filtration. A new technique named blow-pinning that allows coating on a window screen with nanofiber transparent air philtre with an efficiency of > 99 per cent with 80 per cent optical clarity of PM$_{2.5}$ removal by [140]. The average value of the harmonic mean air exchange rate is better below the nationally fixed norms when there are open windows analysed by[141]. Natural ventilation can be improved by reducing the resistance of philtres and that needs further research activities.

C. Anti-Haze Based AC

The Existing AC’s are needed to be customized for purifying PM$_{2.5}$ because of the frequent occurrence of hazy weather that reminding about the importance and essentiality of air quality improvement to people. Familiar air conditioning companies provides AC products enhanced with PM$_{2.5}$ purification functionalities. A novel Cleanable PM$_{2.5}$ purification technic is used in Midea ’s air conditioner (AC) products that generate an electrical field to capture the PM$_{2.5}$ emitting charged particles in the dust collection system with the help of an electrical generator. A visualization functionality to acquire the PM$_{2.5}$ by providing a 5-colour indicator in every AC unit is devised by Haier's air conditioning firm. The indicator turns into red for denoting the high level of PM$_{2.5}$ at indoor and suggests the occupants to turn on the PM$_{2.5}$ removal mode. It turns into blue to indicate the normal level of PM$_{2.5}$. A highly efficient electric field is formed to capture the PM$_{2.5}$ by Panasonic air conditioners. It works by emitting negatively charged 'nanoe-G' that is absorbed by PM$_{2.5}$ present in the air, and that results in negatively charged PM$_{2.5}$ which is easily captured by the electric field. PM$_{2.5}$ is purified by thee combination of three different techniques in Kelon air conditioning products such as stripping, packaging and melting technologies.

D. PM$_{2.5}$ Control strategies in outdoor

A variety of recommendations are needed to carry out since the issue of outdoor air pollution persist to be undetermined. The suggestions are as follows;

- Logical usage of energy.
- Adapting to less-polluting fossil fuels.
- Expanding the usage of non-fossil energy sources.
- Adoption of latest eco friendly combustion techniques
- Framing stern standards over the emissions from air pollutants.
The research works conducted worldwide are aiming to bring an in-depth perception of atmosphere and its associated problems with air pollution especially to human society. Nevertheless, newer methodologies for combustion of fossil fuels and controlling the pollution should be developed. The accessibility and stability in data regarding the air pollutant emissions should be increased and also it should entice the guidelines which are being the most principal part of recommendations in framing the control policies on air pollution.

6. Cities based pollutants impact in India

The pollutants parameters like PM$_{2.5}$, PM$_{10}$, SO$_2$ and NO$_2$ is observed in various cities located in India. Based on the air quality index the colour coding is used to visualize the above parameter. The non marked parameter value is still analysing phase (due data collection human error). Figure 6. Depicts PM$_{2.5}$, Figure 7. Depicts PM$_{10}$, Figure 8. Depicts SO$_2$ and Figure 9. Depicts NO$_2$. The references AQI is listed in Table 1.

| AQI Category (Range) | PM$_{10}$ 24-hr | PM$_{2.5}$ 24-hr | NO$_2$ 24-hr | SO$_2$ 24-hr |
|----------------------|-----------------|-----------------|--------------|--------------|
| Good (0-50)          | 0-50            | 0-30            | 0-40         | 0-40         |
| Satisfactory (51-100) | 51-100          | 31-60           | 41-80        | 41-80        |
| Moderate (101-200)   | 101-250         | 61-90           | 81-180       | 81-380       |
| Poor (201-300)       | 251-350         | 91-120          | 181-280      | 381-800      |
| Very poor (301-400)  | 351-430         | 121-250         | 281-400      | 801-1600     |
| Severe (401-500)     | 430+            | 250+            | 400+         | 1600+        |

Table 1. AQI Scale 0-500 (units: µg/m$^3$)

![Fig 6. Depicts PM$_{2.5}$](image)
Fig. 7 - Depicts PM$_{10}$

Fig. 8 - Depicts SO$_2$
7. Summary

It is clearly evident from recent researches that the concentrations of PM$_{2.5}$ in cities like Mumbai and Delhi has affected the health adversely with increased rate of risks. Prolonged exposure to PM$_{2.5}$ causes mortalities in blood circulation, respiration, hyper tension, lung diseases, COPD and advent of virus in respiratory tract like influenza and these effects in association with PM$_{2.5}$ are assured by latest literature survey. People in Delhi are prone to these hazardous diseases as the city has higher concentrations of PM$_{2.5}$. The PM$_{2.5}$ air quality standards were published in 2012 and that created a considerable drop of 36% in annual proportion of PM$_{2.5}$ from 90μg/m$^3$ in 2012 to 58μg/m$^3$ in 2017[62], but above Indian and International standards (Table 1). The systematic analysis of previous studies established the following targets for future works on PM$_{2.5}$ health effects in India. Organising studies for a prolonged period of years to validate the connections between exposure and health effects. Obtaining finer exposure results with accurate spatial resolutions by deploying high density sampling drives and utilizing satellite based remote sensing techniques. Analysing the mechanisms causing severe health effects, specifically in a multipollutant scenario;
• Recognising the seasonal patterns and sub-population vulnerabilities;
• validating the health effects in order to find the impact of PM’s chemical compounds;
• Constant monitoring of ambient PM$_{2.5}$;
• Investigating the conclusion of ultrafine PM exposure impacts.

Guidelines used in public health need to balance safety measures from hazardous effects and feasibility. The outcomes of this analysis need to demonstrate the arising and alarming need for tightening and revising the public health and environmental policies. Even though some milestones are reached, India has a long way to proceed further for optimising and controlling economic and energy formation. Focusing on these suggestions for future research works and regulations, this review will contribute for achieving a stability between growth and protection with respect to economics and environment.

References

WHO, 2016. Ambient Air Pollution: a Global Assessment of Exposure and Burden of Disease. *World Health Organization*, pp. 40-42.
Liu, G., Liu, H., 2011. Using insulation in China's buildings: potential for significant energy savings and carbon emission reductions. *Low. Carbon Econ.* 2 (4), 220-223.
Diener, E., 1984. Subjective well-being. *Psychol. Bull.* 95 (3), 542-575.
Schmitt, M., 2013. Subjective well-being and air quality in Germany. *Schmollers Jahrb.* 133 (2), 275-286.
Zhang, S.; Wang, Y.; Li, Y.; Zhang, P. Spatial distribution of haze pollution and its influencing factors. China Popular. Resource. Environ. 2017, 27, 15–22.
Ministry of Environmental Protection of the People’s Republic of China. Bulletin on Environmental Conditions in China in 2015. http://www.mep.gov.cn/hjzl/zghjzkgb/lnzghjzkgb/201606/P020160602333160471955.pdf
Ministry of Environmental Protection of the People’s Republic of China. *Bulletin on Environmental Conditions in China in 2016*. http://www.mep.gov.cn/hjzl/zghjzkgb/lnzghjzkgb/201706/ P020170605833655914077.pdf
Liang, Z.; Ma, M.; Du, G. Comparison of characteristics and trend analysis of atmospheric pollution in Beijing–Tainji–Shijiazhuang during 2003–2012. *Environ. Eng.* 2014, 12, 76–81.
Bergen S, Sheppard L, Sampson PD, et al. A national prediction model for PM2.5 component exposures and measurement error–corrected health effect inference. *Environ Health Perspect* 2013; 121: 1017-25.
Stro B, Lipsett M, Reynolds P; et al. Long-term exposure to constituents of fine particulate air pollution and mortality: results from the California Teachers Study. *Environ Health Perspect* 2010; 118: 363-9.
Pope CA 3rd, Burnett RT, Thun MJ, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 2002;287:1132-41.

Sun S, Qiu H, Ho KF, et al. Chemical components of respirable particulate matter associated with emergency hospital admissions for type 2 diabetes mellitus in Hong Kong. Environ Int 2016;97:93-9.

Bernard, S.M., Samet, J.M., Grambsch, A., Ebi, K.L., Romieu, I., 2001. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environ. Health Perspect. 109 (Suppl. 2), 199–209.

Wong, T.W., Tam, W., Yu, I.T.S., Wun, Y.T., Wong, A.H.S., Wong, C.M., 2006. Association between air pollution and general practitioner visits for respiratory diseases in Hong Kong. Thorax 61, 585–591.

Chang, H.H., Hao, H., Sarnat, S.E., 2014. A statistical modelling framework for projecting future ambient ozone and its health impact due to climate change. Atmos. Environ. 89,290–297.

Samoli, E., Stafoggia, M., Rodopoulou, S., Ostro, B., Declercq, C., Alessandrini, E., Diaz, J., Karanasiou, A., Kelessis, A.G., Le Tertre, A., Pandolfi, P., Randi, G., Scarinzi, C., Zauli-Sajani, S., Katsouyanni, K., Forastiere, F., 2013. Associations between fine and coarse particles and mortality in Mediterranean cities: results from the MED-PARTICLES project. Environ. Health Perspect. 121, 932–938.

Guo, Y., Li, S., Tian, Z., Pan, X., Zhang, J., Williams, G., 2013. The burden of air pollution on years of life lost in Beijing, China, 2004–08: retrospective regression analysis of daily deaths. BMJ 347.

Selin, N.E., Wu, S., Nam, K.M., Reilly, J.M., Paltsev, S., Prinn, R.G., Webster, M.D., 2009. Global health and economic impacts of future ozone pollution. Environ. Res. Lett. 4,044014.

Fang, Y., Mauzerall, D., Liu, J., Fiore, A., Horowitz, L., 2013. Impacts of 21st century climate change on global air pollution-related premature mortality. Environ. Res. Lett. 8,044014.

Kinney, P.L., 2008. Climate change, air quality, and human health. Am. J. Prev. Med. 35,459–467.

Kumar, S., Goyal, A., 2016. Long-term health effects of particulate matter air pollution on cardiovascular system: a double-blind randomized controlled trial. J. Community Med. 11,111–114.

Kinney, P.L., 2008. Climate change, air quality, and human health. Am. J. Prev. Med. 35,459–467.

Sujariitpong, S., Dear, K., Cope, M., Walsh, S., Kjellstrom, T., 2014. Quantifying the health impacts of air pollution under a changing climate—a review of approaches and methodology. Int. J. Biometeorol. 58 (2), 149–160.

D’Amato G, Pawankar R, Vitale C, Maurizia L. Climate change and Air Pollution: Effects on Respiratory Allergy. Allergy, Asthma Immunology Research. 2016 Sep; 8(5), 391- 395, doi: 10.4168/airr.2016.8.5.391

Watson JT, Gayer M, Connolly MA. Epidemics after Natural Disasters. Emerg Infect Dis. 2007 Jan; 13(1):1–5.

Lindh E, Argentini C, Remoli ME, Fortuna C, Faggioni G, Benedetti E, et al. The Italian 2017 Outbreak Chikungunya Virus Belongs to an Emerging Aedes albopictus–Adapted Virus Cluster Introduced From the Indian Subcontinent. Open Forum Infect Dis 2019 Jan; 6(1): ofy321, doi: 10.1093/ofid/ofy321

Calba C, Guerbois-Galla M, Franke F, Jeannin C, Auzet-Caillaud M, Grard G,Pigaglio L, Decoppet A, Weicherding J, Savaill MC, Munoz-Riviero M, Chaud P,Cadiou B, Ramalli L, Fournier P, Noël H, De Lamballerie X, Paty MC, Leparc-Goffart I. Preliminary report of an autochthonous chikungunya outbreak in France, July to September 2017. Euro Surveill. 2017 Sept; 22(39); pii=17-00647.https://doi.org/10.2807/1560-917.ES.2017.22.39.17-00647
Wilson WE, Suh HH. Fine Particles and Coarse Particles: Concentration Relationships Relevant to Epidemiologic Studies. J Air Waste Manag Assoc. 1997 Dec;47(12):1238–1249.

US EPA (US Environmental Protection Agency). 2018. pollution/particulate-matter-pm-basics

Cheung K, Daher N, Kam W, Shafer MM, Ning Z, Schauer JJ, et al. Spatial and temporal variation of chemical composition and mass closure of ambient coarse particulate matter (PM_{10}–PM_{2.5}) in the Los Angeles area. Atmos Environ. 2011 May 1;45(16):2651–2662.

Zhang L, Yang Y, Li Y, Qian ZM, Xiao W, Wang X, Rolling CA, Liu E, Xiao J, Zeng W, Liu T, Li X, Yao Z, Wang H, Ma W, Lin H. Short-term and long-term effects of PM 2.5 on acute nasopharyngitis in 10 communities of Guangdong, China. Sci Total Env, 20 Oct 2019, 688, 136-142.

Kloog I, Ridgway B, Koutrakis P, Coull BA, Schwartz JD. Long- and Short-Term Exposure to PM 2.5 and Mortality Using Novel Exposure Models, Epidemiology. 2013 Jul; 24(4): 555–561. doi:10.1097/EDE.0b013e318294beaa

New Hampshire Department of Environmental Services. Current and Forecasted Air Quality in New Hampshire. Environmental Fact Sheet. 2019. https://www.des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-16.pdf

Kappos AD, Bruckmann P, Eikmann T, Englert N, Heinrich U, Höppe P, et al. Health effects of particles in ambient air. Int J Hyg Environ Health. 2004 Jan 1; 207(4):399–407.

Boschi N. Education and Training in Indoor Air Sciences. Springer Science & Business Media; 2012. p.245

Villányi V, Turk B, Franc B, Csintalan Z. Ozone Pollution and its Bioindication. In: 2010.

Massachusetts Department of Public Health. Massachusetts State Health Assessment. Boston, MA; October 2017. https://www.mass.gov/files/documents/2017/11/03/2017%20MA%20SHA%20final%20compressed.pdf

Lorenzini G, Saitanis C. Ozone: A Novel Plant “Pathogen.” 2003; p. 205–229, doi:10.1007/978-94-017-0255-3_8

Fares S, Vargas R, Detto M, Goldstein AH, Karlik J, Paoletti E, et al. Tropospheric ozone reduces carbon assimilation in trees: estimates from analysis of continuous flux measurements. Glob Change Biol. 2013 Aug; 19(8):2427–2443.

Harmens H, Mills G, Hayes F, Jones L, Norris D, Fuhrer J. Air pollution and vegetation: ICP Vegetation Annual Report 2006/2007. 2012. Sep 1; ISBN: 978-1-906698-35-5

Emberson LD, Pleijel H, Ainsworth EA, den Berg M, Ren W, Osborne S, Mills G, Pandey D, Dentener F, Büker P, Ewert F, Koebke R, Van Dingenen R. Ozone effects on crops and consideration in crop models. Eur J Agron .2018 Oct; 100:19-34.

Alexopoulos A, Plessas S, Ceciu S, Lazar V, Mantzourani I, Voidarou C, et al. Evaluation of ozone efficacy on the reduction of microbial population of fresh cut lettuce (Lactuca sativa) and green bell pepper (Capsicum annuum). Food Control. 2013 Apr 1;30:491–496.

Alexopoulos A, Plessas S, Kourkoutas Y, Stefanis C, Vavias S, Voidarou C, et al. Experimental effect of ozone upon the microbial flora of commercially produced dairy fermented products. Int J Food Microbiol. 2017 Apr 4;246:5–11.

Maggio A, Fagnano M. Ozone Damages to Mediterranean Crops: Physiological Responses. Ital J Agron. 2008 Mar 31;13–20.
McCarthy JT, Pelle E, Dong K, Brahmbhatt K, Yarosh D, Pernodet N. Effects of ozone in normal human epidermal keratinocytes. Exp Dermatol. 2013 May;22(5):360–36.

WHO. Health risks of ozone from long-range transboundary air pollution. http://www.euro.who.int/data/assets/pdf_file/0005/78647/E91843.pdf

Thiele JJ, Traber MG, Tsang K, Cross CE, Packer L. In vivo exposure to ozone depletes vitamins C and E and induces lipid peroxidation in epidermal layers of murine skin. Free Radical Biology & Medicine, 1997, 23:365–391.

Hatch GE, Slade R, Harris LP, McDonnell WF, Devlin RB, Koren HS, Costa DL, McKee J. Ozone dose and effect in humans and rats. A comparison using oxygen-18 labeling and bronchoalveolar lavage. Am J Respir Crit Care Med. 1994 Sep;150(3):676-83.

Lippmann M. Health effects of ozone. A critical review. JAPCA. 1989 May;39(5):672–95.

Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J, Samoli E, Medina S, Anderson HR, Niciu EM, Wichmann HE, Kriz B, Kosnik M, Skorkovsky J, Vonk JM, Dörbudak Z. Acute effects of ozone on mortality from the "air pollution and health: a European approach" project. Am J Respir Crit Care Med. 2004 Nov 15;170(10):1080-1087.

Hesterberg TW, Bunn WB, McClellan RO, Hamade AK, Long CM, Valberg PA. Critical review of the human data on short-term nitrogen dioxide (NO2) exposures: evidence for NO2 no-effect levels. Crit Rev Toxicol. 2009; 39(9):743–81.

Chen T-M, Gokhale J, Shofer S, Kuschner WG. Outdoor air pollution: nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects. Am J Med Sci. 2007 Apr; 333(4):249–56.

World Health Organization. Air Quality Guide-lines for Europe. Copenhagen, Denmark: WHO, Regional Office for Europe (in press).

Adhikari DP. A report on air pollution situational analysis and management plan. Kathmandu, Nepal: World Health Organization/Nepal and Department of Water Supply and Sewerage. 1999

Romieu I. Epidemiological studies of health effects arising from motor vehicle air pollution. In: Schwela D, Zali O, eds, Urban Traffic Pollution. London, UK: E & FN Spon, 1999; 9-69.

Schlesinger RB. Toxicology of sulfur oxides. In: Holgate ST, Samet JM, Koren HS, Maynard RL, eds, Air Pollution and Health. London, UK: Academic Press, 1999; 585-602.

U.S. Environmental Protection Agency. Air quality criteria for oxides of nitrogen. Research Triangle Park, North Carolina, USA: Environmental Criteria and Assessment Office, EPA-600/8-91/049a-F-Cf.3v,1993.

World Health Organization. Nitrogen Oxides. Environmental Health Criteria 188. Geneva, Switzerland: WHO, 1997.

Hazucha MJ. Controlled exposure to ozone, nitrogen oxides and acids. In: Holgate ST, Samet JM, Koren HS, Maynard RL, eds, Air Pollution and Health. London, UK: Academic Press, 1999; 511-530.

Ackermann-Liebrich U, Rapp R. Epidemiological effects of oxides of nitrogen, especially N02. In: Holgate ST, Samet JM, Koren HS, Maynard RL, eds, Air Pollution and Health. London, UK: Academic Press, 1999; 559-584.

Chauhan AJ, Krishna MT, Frew AJ, Holgate SJ. Exposure to nitrogen dioxide (N02) and the risk of respiratory disease. Rev Environ Health 1998;13: 91-98.
Hasselblad V, Eddy DM, Kotchmar DJ. Synthesis of environmental evidence: Nitrogen dioxide epidemiology studies. J Air Waste Management Assoc 1992; 42: 662-671.

Ostro BD, Lipsett MJ, Mann JK, Krupnick A, Harrington W. Air pollution and respiratory morbidity among adults in Southern California. Am J Epidemiol 1993; 137: 691-700.

Jarvis D, Chinn S, Sterne J, Luczynska C, Burney P. The association of respiratory symptoms and lung function with the use of gas for cooking. Eur Respir J 1998; 11: 651-658.

Pilotto LS, Douglas RM, Attewell RG, Wilson SR. Respiratory effects associated with indoor nitrogen dioxide exposure in children. Int J Epidemiol 1997; 26: 788-796.

Tunnicliffe WS, Bürge PS, Ayres JG. Effect of domestic concentrations of nitrogen dioxide on airway responses to inhaled allergen in asthmatic patients. Lancet 1994; 344: 1733-1736.

Strand V, Rak S, Svartengren M, Bylin G. Nitrogen dioxide exposure enhances asthmatic reaction to inhaled allergen in subjects with asthma. Am J Respir Crit Care Med 1997; 155: 881-887.

Schwartz J, Dockery DW, Neas LM, Wypij D, Ware JH, Spengler JD, et al. Acute effects of summer air pollution on respiratory symptom reporting in children. Am J Respir Crit Care Med 1994; 150: 1234-1242.

Quacke boss JJ, Krzyzanowski M, Lebowitz MD. Exposure assessment approaches to evaluate respiratory health effects of particulate matter and nitrogen dioxide. J Exposure Anal Environ Epidemiol 1991; 1: 83 - 107.

Linn W S, S h a m o o DA, Anderson K R, Peng RC, Avol EL, Hackney JD, O n g H Jr. Short-term air pollution exposures and responses in Los Angeles area schoolchildren. J Exposure Anal Environ Epidemiol 1996; 6: 449 – 172.

Roemer W, Hoek G, Brune kreef B. Effect of ambient winter air pollution on respiratory health of children with chronic respiratory symptoms. Am Rev Respir Dis 1993; 147: 118-124.

Hoek G, Brune kreef B. Effects of low-level winter air pollution concentrations on respiratory health of Dutch children. Environ Res 1994; 64: 136-150.
Schwartz J, Zeger S. Passive smoking, air pollution, and acute respiratory symptoms in a dairy study of student nurses. Am Rev Respir Dis 1990; 141: 62-67.

Linn W S, S h a m o o DA, Anderson K R, Peng RC, Avol EL, Hackney JD, G o n g H Jr. Short-term air pollution exposures and responses in Los Angeles area schoolchildren. J Exposure Anal Environ Epidemiol 1996; 6: 449- 172.

Bevan M A J, Proctor CJ, Baker Rogers J, Warren N D. Exposure to carbon monoxide, respirable suspended particulates, and volatile organic compounds while commuting by bicycle. Environ Sci Technol 1991; 25: 788 - 791.

Van Wijnen JH, Verhoeoff AP, Jans H W, van Brüggen M. The exposure of cyclists, car drivers and pedestrians to traffic-related air pollutants. Int Arch Occup Environ Health 1995; 67: 187-189.

Rudolf W. Concentration of air pollutants inside cars driving on highways and in downtown areas. Sei Total Environ 1994; 176: 146 - 147.

Dor F, Le-Moullec Y, Festy B. Exposure of city residents to carbon monoxide and monocyclic aromatic hydrocarbons during commuting trips in the Paris metropolitan area. J Air Waste Management Assoc 1995; 45: 103-110.

Fernandez-Bremauntz AA, Ashmore MR. Exposure of commuters to carbon monoxide in Mexico City. II. Comparison of in-vehicle and fixed-site concentrations. J Exposure Anal Environ Epidemiol 1995; 5: 497-510.

Van Wijnen JH, van der Zee SC. Traffic-related air pollutants: Exposure of road users and populations living near busy roads. Rev Environ Health 1998; 13: 1-26.

Chan C C, Özkaynak H, Spengler JD, Sheldon L. Driver exposure to volatile organic compounds, CO, ozone, and NO2 under different driving conditions. Environ Sci Technol 1991; 25: 964 - 972.

Zhang Yi, Stedman DH, Bishop GA, Guenther PL, Beaton SP. Worldwide on-road vehicle exhaust emissions study by remote sensing. Environ Sci Technol 1995; 29: 2286 - 2294.

Chow WK. Prediction of CO level near vehicular tunnel with waiting queue. J Environ Eng 1991; 117: 116-125.

De Fre R, Bruynseraede P, Kretzschmar JG. Air pollution measurements in traffic tunnels. Environ Health-Perspect 1994; 102(Suppl. 4), 31-37.

Salonen RO et al. Carbon monoxide poisonings during a junior ice hockey tournament. Am J Respir Crit Care Med 1994; 153: 3 - 50 (Part 1); 477 - 498.

Hampson NB. Carbon monoxide poisoning at an indoor ice arena and bingo hall-Seattle, 1996. Morbid Mortal Weekly Rep 1996; 45: 265 – 267.

U.S. Environmental Protection Agency. Air quality criteria for carbon monoxide. Washington, DC, USA: Office of Research and Development, EPA-600/B-90/045F, 1991.

Bascom R, Bromberg PA, Costa, DA, Devlin R, Dockery DW, Frampton MW, et al. Health effects of outdoor air pollution. Am J Respir Crit Care Med 1996; 153:3 - 50 (Part 1); 477 - 498.

Romieu I. Epidemiological studies of health effects arising from motor vehicle air pollution. In: Schwela D, Zali O, eds, Urban Traffic Pollution. London, UK: E & FN Spon, 1999; 9-69.

Schlesinger RB. Toxicology of sulfur oxides. In: Holgate ST, Samet JM, Koren HS, Maynard RL, eds, Air Pollution and Health. London, UK: Academic Press, 1999; 585-602.
Derrienic F, Richardson S, Mollie A, Lellouch J Short-term effects of Sulfur dioxide pollution on mortality in two French cities. Int J Epidemiol 1989; 18: 186-197.

Ackermann-Liebrich U, Leuenerberger P, Schwartz J, Schindler C, Monn C, Bolognini G, et al. Lung function and long term exposure to air pollutants in Switzerland. Study on Air Pollution and Lung Diseases in Adults (SAPALDIA) Team. Am J Respir Crit Care Med 1997; 155: 122-129.

WHO (World Health Organization). Comparative quantification of health risks .p.1495- 1542 https://www.who.int/healthinfo/global_burden_disease/cra/en/

Goyer RA. Transplacental transport of lead. Environ Health Perspect. 1990 Nov;89:101-105.

Farhat A, Mohammadzadeh A, Balali-Mood M, Aghajanpoor-Pasha M, Ravanshad Y. Correlation of Blood Lead Level in Mothers and Exclusively Breastfed Infants: A Study on Infants Aged Less Than Six Months. Asia Pac J Med Toxicol. 2013 Dec 1;2(4):150–152.

Assi MA, Hezme MNM, Haron AW, Sabri MYM, Rajion MA. The detrimental effects of lead on human and animal health, Vet World. 2016 Jun; 9(6): 660–671.doi: 10.14202/vetworld.2016.660-671

WHO (World Health Organization). Dioxins and their effects on human health [Internet]. [cited 2019 Oct 5]. Available from: https://www.who.int/news-room/fact-sheets/detail/dioxins-and-their-effects-on-human-health.

Nakano T, Otsuki T. Environmental air pollutants and the risk of cancer. Gan To Kagaku Ryoho. 2013 Nov; 40(11):1441–1445.

Atkinson RW, Fuller GW, Anderson HR, Harrison RM, Armstrong B. Urban ambient particle metrics and health. A time series analysis. Epidemiology 2010;21:501–11.

Chuang K-J, Yan Y-H, Chiu S-Y, Cheng TJ. Long-term air pollution exposure and risk factors for cardiovascular diseases among the elderly in Taiwan. Occup Environ Med 2011;68:64–8.

Johansson C, Norman M, Gidhagen L. Spatial & temporal variations of PM 10 and particle number concentrations in urban air. Environ Monit Assess 2007;127(1–3):477–87.

Madureira J, Paciência I, Fernandes EO. Levels and indoor–outdoor relationships of size-specific particulate matter in naturally ventilated Portuguese schools. J Toxicol Environ Health A 2012;75(22–23):1423–36.

Kabir E, Kim K-H, Sohn JR, Kweon BY, Shin JH. Indoor air quality assessment in child care and medical facilities in Korea. Environ Monit Assess 2012;184:6395–409.

Shi, J.; Yuan, D.; Zhao, Z. Residential indoor PM 2.5 sources, concentration and influencing factors in China.J. Environ. Health 2015, 32, 825–829.

Zhang, S.; Duan, Y. Determination the PM 2.5 concentration in the room of Liting mosquito-repellent incense and cigarette. Inn. Mong. Environ. Sci. 2013, 25, 184–185.

Li, T.; Cao, S.; Fan, D.; Zhang, Y.; Wang, B.; Zhao, X.; Leaderer, B.P.; Shen, G.; Zhang, Y. Duan, X. Household concentrations and personal exposure of PM 2.5 among urban residents using different cooking fuels. Sci. Total Environ. 2016, 548–549, 6–12. [PubMed]

Zhou, Z.; Liu, Y.; Yuan, J.; Zuo, J.; Chen, G.; Xu, L.; Rameezdeen, R. Indoor PM 2.5 concentrations in residential buildings during a severely polluted winter: A case study in Tian, China. Renew. Sustain. Energy Rev. 2016,64, 372–381.

Gui, F.; Ye, Q.; Zhou, Y.; Huang, H. Influences of sweeping on the Concentration of Particulate Matter in the indoor air. J. Anhui Univ. Technol. Nat. Sci. 2013, 30, 250–254.
Zhang, N.; Han, B.; He, F.; Xu, J.; Zhao, R.; Zhang, Y.; Bai, Z. Chemical characteristic of PM 2.5 emission and inhalational carcinogenic risk of domestic Chinese cooking. Environ. Pollut. 2017, 227, 24–30. [PubMed]

Pui, D.Y.H.; Chen, S.C.; Zui, Z. PM 2.5 in China: Measurements, sources, visibility and health effects, and mitigation. Particuology 2014, 13, 1–26.

Chen, R.; Li, Y.; Ma, Y.; Pan, G.; Zeng, G.; Xu, X.; Chen, B.; Kan, H. Coarse particles and mortality in three Chinese cities: The China air pollution and health effects study (CAPES). Sci. Total Environ. 2011, 409, 4934–4938. [PubMed]

Guo, Y.; Jia, Y.; Pan, X.; Liu, L.; Wichmann, H.E. The association between fine particulate air pollution and hospital emergency room visits for cardiovascular diseases in Beijing, China. Sci. Total Environ. 2009, 407, 4826–4830. [PubMed]

Guo, Y.; Tong, S.; Zhang, Y.; Barnett, A.G.; Jia, Y.; Pan, X. The relationship between particulate air pollution and emergency hospital visits for hypertension in Beijing, China. Sci. Total Environ. 2010, 408, 4446–4450. [PubMed]

Li, P.; Xin, J.; Wang, Y.; Wang, S.; Li, G.; Pan, X.; Liu, Z.; Wang, L. The acute effects of fine particles on respiratory mortality and morbidity in Beijing, 2004–2009. Environ. Sci. Pollut. Res. Int. 2013, 20, 6433–6444. [PubMed]

Zheng, S.; Pozzer, C.; Cao, X.; Lelieveld, J. Long-term (2001–2012) concentrations of fine particulate matter (PM 2.5) and the impact on human health in Beijing, China. Atmos. Chem. Phys. 2015, 15, 5715–5725.

Du, Y.; Li, T. An assessment of health-based economic costs linked to fine particulate (PM 2.5) pollution: A case study of haze during January 2013 in Beijing, China. Air Qual. Atmos. Health 2016, 9, 439–445.

Air quality guidelines: global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen, WHO Regional Office for Europe, 2006 (http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide).

Samoli E et al. Acute effects of ambient particulate matter on mortality in Europe and North America: results from the APHENA Study. Environmental Health Perspectives, 2008, 116(11):1480–1486.

Beelen R et al. Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR Study). Environmental Health Perspectives, 2008, 116(2):196–202.

Krewski D et al. Extended follow-up and spatial analysis of the American Cancer Society linking particulate air pollution and mortality. Boston, MA, Health Effects Institute, 2009

Pope CA III et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association, 2002, 287(9):1132–1141.

Ashfaq A, Sharma P. Environmental effects of air pollution and application of engineered methods to combat the problem. J Indust Pollut Control .2012 Dec; 29 (1) . Available from: http://www.icontrolpollution.com/ peer-reviewed/ environmental-effects-of-air- pollution-and-application-of-engineered-methods-to-combat-the-problem-45739.html

Madronich S, de Gruijl F. Skin Cancer and UV radiation. Nature. 1993 Jan 13;366: 23-29.118.

Teramura A. Effects of UV-B radiation on the growth and yield of crop plants. Physiol Plant. 2006 Apr 28; 58:415–427.
Manderson L. How global warming is adding to the health risks of poor people [Internet]. The Conversation. [cited 2019 Oct 5]. Available from: http://theconversation.com/how-global-warming-is-adding-to-the-health-risks-of-poor-people-109520.

Singh E, Tiwari S, Agrawal M. Effects of elevated ozone on photosynthesis and stomatal conductance of two soybean varieties: a case study to assess impacts of one component of predicted global climate change. Plant Biol Stuttg Ger. 2009 Nov; 11 Suppl 1:101–108.

Ministers of Energy and Environment. Federal/Provincial/Territorial Ministers of Energy and Environment (Canada), editor. The Canada-wide acid rain strategy for post-2000. Halifax, N.S: The Ministers; 1999. p.11

Cao, G.; Xie, H.; Zhao, S. Strategic Research of Pollution Control of Indoor PM 2.5 in Public Buildings. Build. Sci.2015, 31.

Wang, X. The PM 2.5 Filtration Performance and Comprehensive Assessment of Air Filter Used in Fresh Air Unit. Ph.D. Thesis, Chongqing University, Chongqing, China, 2016.

Lv, X.; Zhang, L.; Liu, Z.; Xu, X. Primary return air system PM 2.5 control strategy. J. Environ. Eng. 2016, 10, 7141–7146.

Zhao, X.; Li, Y.; Hua, T.; Jiang, P.; Yin, X.; Yu, J.; Ding, B. Low-Resistance Dual-Purpose Air Filter Releasing Negative Ions and Effectively Capturing PM 2.5. ACS Appl. Mater. Interfaces 2017, 9, 12054–12063. [PubMed]

Zhang, R.; Liu, C.; Hsu, P.C.; Zhang, C.; Liu, N.; Lee, H.R.; Lu, Y.; Qiu, Y.; Chu, S.; Cui, Y. Nanofiber Air Filters with High-Temperature Stability for Efficient PM 2.5 Removal from the Pollution Sources. Nano Lett.2016, 16, 3642–3649. [PubMed]

Li, M.; Feng, Y.; Wang, K.; Yong, W.F.; Yu, L.; Chung, T.S. Novel Hollow Fiber Air Filters for the Removal of Ultrafine Particles in PM 2.5 with Repetitive Usage Capability. Environ. Sci. Technol. 2017, 51, 10041–10049. [PubMed]

Liu, C.; Hsu, P.C.; Lee, H.W.; Ye, M.; Zheng, G.; Liu, N.; Li, W.; Cui, Y. Transparent air filter for high-efficiency PM 2.5 capture. Nat. Commun. 2015, 6. [PubMed]

Zhao, X.; Wang, S.; Yin, X.; Yu, J.; Ding, B. Slip-Effect Functional Air Filter for Efficient Purification of PM 2.5. Sci. Rep. 2016, 6, 35472. [PubMed]

Khalid, B.; Bai, X.; Wei, H.; Huang, Y.; Wu, H.; Cui, Y. Direct Blow-Spinning of Nanofibers on a Window Screen for Highly Efficient PM 2.5 Removal. Nano Lett. 2017, 17, 1140–1148. [PubMed]

Shi, S.; Bian, Y.; Zhang, L.; Chen, C. A method for assessing the performance of nanofiber films coated on window screens in reducing residential exposures to PM 2.5 of outdoor origin in Beijing. Indoor Air 2017, 27,1190–1200. [PubMed].