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Effects of particulate matter from air pollution on cardiovascular system of the body

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Abstract

Air pollution is a mixture of particulate and gaseous components, which will have adverse effects on human health. Depending upon Cause of air pollution, composition varies, and studies from all over the world shown that air pollution has increased mortality. More than gaseous components, particulate matter has greater impact on health, which is proved by several clinical studies. Particulate components have wide effect on human health especially cardiovascular system of the body. There is increased risk of death from both chronic and acute exposure to PM air pollution. Acute exposure had led to wide range of cardiovascular events like hospital admissions with angina, heart failure, myocardial infarction. Long term exposure led to risk of death from coronary heart disease. Particulate matter from air pollution has been also shown as important factor contributing to obesity and diabetes. An understanding of how PM causes toxic effects on human health is important to prevent and minimize the health effects. Public health problems and mortality rate because of air pollution are expected to double by 2050. In this paper we will review how PM exerts toxic effects on cardiovascular system, and discuss about major studies that established link between particulate matter (PM) air pollution and cardiovascular disease in the humans.

Keywords: Air pollution, gaseous components, increased mortality

Introduction

Air pollution is a global health problem which causes an estimated death of 3.1 million per year^[1, 2, 3]. Majority of the deaths due to air pollution exposure are due to thrombotic (acute ischemic) cardiovascular events. It not only causes mortality, but silently reduces the healthy life span and worker productivity^[2, 4]. Health risk due to exposure of air pollution is the largest environmental health risk, which ranks ninth among other causes. In developed countries air pollution standards are way below target standards^[6, 7]. Air pollution is also an important endocrine disrupter, causing the metabolic diseases like diabetes mellitus^[5].

Air Pollution

Air pollution is a mixture of particulate and gaseous components which has adverse effects on respiratory and cardiovascular systems. The composition of particulate matter depends on the source of air pollution, emission rate wind conditions and sunlight. Nitric oxide (NO), Nitrogen Dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃), and carbon monoxide (CO) are the main gaseous components which indicate air pollution^[2, 15, 16]. Particulate Matter of air pollution contains carbonaceous particles with associated absorbed reactive metals and organic chemicals. Nitrates, Sulphates, endotoxin, polycyclic hydrocarbons, and metals such as Nickel, Zinc, copper^[2, 9, 10]. Particulate Matter of air pollution is classified into different categories based on Particle size. First one of category is coarse (PM₁₀, diameter <10µm), second is fine (PM_{2.5}, diameter <2.5µm), and third is ultrafine (PM_{0.1}, diameter <0.1µm). Source of coarse particles is from natural and industrial sources and usually do not penetrate beyond upper bronchus. Sources of fine and ultra-fine particles are combustion of fossil fuels, and these particles are of greater threat to health and can penetrate smaller airways^[11, 12].

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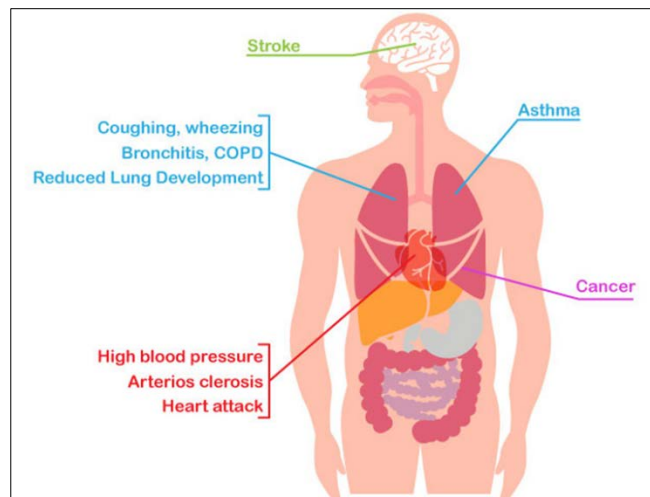


Fig 1: Different affects of air pollution on Human body

Cardiovascular effects

Myocardial ischaemia

During the submaximal exercise tolerance testing in elder patients who has heart coronary heart disease, it was noticed that exposure to PM of air pollution has increased the risk of ST-segment depression [13, 14, 15]. This risk was higher when the exposed to combustion derived particulate matter [15]. Similarly a test was conducted and recordings were taken while doing exercise outdoors, before and after the exercise, and exposure to black carbon derived from traffic has increased ST-segment depression in elder heart patients [16]. ST-segments depression has increased in elderly patients with coronary heart disease during 24 hour electrocardiographic recordings due to the exposure of black carbon and PM_{2.5} exposure [17]. The same thing is observed in patients of acute coronary syndromes [18]. A study was conducted on patients in Beijing using face mask and walking around in the center of Beijing and it was noticed that ST-segment depression was reduced [19]. Recent studies on association of new Coronavirus COVID-19 has increased threat to heart myocardial injury [20].

Vasoconstriction and arterial stiffness

In a study by [21] which is done by controlled exposure of concentrated ambient particles from air pollution in order to assess vascular function, demonstrated the occurrence of vasoconstriction of the brachial artery. Similar study was made on healthy people and people with metabolic syndrome and acute vasoconstriction was observed after being exposed to diesel exhaust [22]. In another cardiovascular study, based on exposure to air pollution which was measure using portable monitoring equipment, and it was found that exposure to particulate matter, increased the vasoconstriction [23]. It was demonstrated that there is an immediate increase in central arterial stiffness after being exposed to dilute diesel exhaust with also an increase in arterial tone and vasoconstriction [24]. In a study which is done on children, central arterial stiffness is found to higher in children living close to major roads, than children living far away from heavily pouted areas due to traffic [25].

Oxidative stress, Inflammation

PM inhalation induces inflammatory responses within lungs. In a study which was done on some volunteers, they are exposed to PM via inhaling process for about two hours, has

increased pulmonary neutrophil numbers [26]. Systemic inflammatory can mediate the exposure to air pollution to local responses which in turn is driven by oxidative stress. Some studies showed the association between PM air pollution and acute phase response by increase in plasma viscosity [27], C-reactive protein [28] and fibrinogen [29].

Biological effects via Oxidative stress or generation of reactive oxygen species (ROS) is associated with PM [30, 31]. Systemic makers of oxidative stress is associated with air pollution exposure [32, 33, 34]. Many cell types respond with elevations in cellular ROS levels and oxidative stress due to PM exposure. This includes lung epithelial cells, nasal, airway, macrophages, gastrointestinal epithelial cells, cardiomyocytes and corneal epithelial cells [35-41]. PM exposure also is associated with systemic makers of oxidative stress, including atherogenic precursors, oxidized lipids [42-45].

Cardiac arrhythmias and Cardiac rate variability

Incidence of cardiac arrhythmias including ventricular tachycardia and atrial fibrillation, and ventricular fibrillation are associated with Short term exposure to air pollution [45]. Heart rate increase is associated with exposure to air pollution along with electric instability, ectopic beats, repolarization irregularities and changes in heart rate variability [56].

In a study [45] done on people with arrhythmia, a strong correlation between occurrence of arrhythmia and pollution exposure has been found and it concludes that risk of arrhythmias is more in people who already have it. Another study done on wild type of mice suggested that no occurrence of arrhythmia is found in mice after exposure to PM, but arrhythmias is seen in mice engineered to exhibit cardiomyopathic changes that resemble to heart failure [47]. Epidemiological studies demonstrated that short term exposure to PM air pollution has increased hospital admissions with heart failure, and arrhythmias. Exposure to PM has associated incidence of ventricular arrhythmias in patients with automated implantable defibrillators. Sudden cardiac death is associated with ventricular arrhythmias with the activity of the autonomic nervous system. In susceptible patients there is likelihood of developing ventricular arrhythmias due to reduced heart the variability [48].

Following a 2-hour exposure to PM in healthy elderly people, heart rate variability has reduced, and remained weakened up to 24 hour after the exposure [49]. [50] Healthy volunteers are exposed to PM of different size fractions and changes in heart rate variability are assessed and it was found that there is no relationship between heart rate variability and exposure to different sizes of PM particles. But it was found that there is a reduction in indices of heart rate variability by exposure to coarse particles between 2.5 and 10 μm in diameter. Due to the recent pandemic and quarantine caused by Coronavirus there is a significant reduction in levels of NO₂, and air pollution has reduced due to less traffic [46].

Blood pressure

Association of hypertension and air pollution has been studied extensively and has been the subject of these different studies [51, 52, 53, 54]. An elevation in systolic acid and diastolic blood pressure with 1 to 3 mm Hg are associated with an increase in ambient PM_{2.5} by 10 $\mu\text{g}/\text{m}^3$. There is an increase in blood pressure noticed in people who are

exposed to long term air pollution with an incidence of hypertension in many studies as well. In studies which are controlled, performed on humans, association of air pollution with a variety of vascular alterations resulted in changes of blood pressure^[55]. Some strategies used to lower air pollution demonstrated fact effects in reducing blood pressure, by confirming the direct impact of inhalation of air on blood pressure. This evidence supports the impact of air pollution on inclusion of higher blood pressure and hypertension. In a study sugarcane harvester found that, during the harvest time, at the time of burning sugarcane the PM is high and due to inhaling it workers blood pressure and heart rate variability measurements correlated with sympathetic nerve activity.

Conclusion

It is very evident that air pollution is a major cause to cardiovascular mortality and morbidity. Exposing ourselves to pollution is a major modifiable risk in managing the prevention of cardiovascular disease, and effects of air pollution are not just limited to cardiovascular system of body. PM is also a contributor to development of metabolic diseases like obesity and diabetes is also studied that puberty in men and women can also be effected by air pollution. Air pollution also affects central nervous system, and gastrointestinal tract. There is no safe level of PM exposure, so in addition to putting efforts to reduce air pollution and exposure, studies should focus on mechanisms to better understand how PM can cause adverse health effects. There should be awareness that should be brought in the public, education on the harmful effects of air pollution especially on patients with underlying health issues. And finally, we all should contribute in our daily levels to lessen the air pollution.

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