Review Article

The Emerging Role of Outdoor and Indoor Air Pollution in Cardiovascular Disease

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Abstract

Outdoor and indoor air pollution poses a significant cardiovascular risk, and has been associated with atherosclerosis, the main underlying pathology in many cardiovascular diseases. Although, it is well known that exposure to air pollution causes pulmonary disease, recent studies have shown that cardiovascular health consequences of air pollution generally equal or exceed those due to pulmonary diseases. The objective of this article is to evaluate the current evidence on the emerging role of environmental air pollutions in cardiovascular disease, with specific focus on the types of air pollutants and mechanisms of air pollution-induced cardiotoxicity. Published literature on pollution was systematically reviewed and cited in this article. It is hoped that this review will provide a better understanding of the harmful cardiovascular effects induced by air pollution exposure. This will help to bring a better understanding on the possible preventive health measures and will also serve regulatory agencies and researchers. In addition, elucidating the biological mechanisms underlying the link between air pollution and cardiovascular disease is an essential target in developing novel pharmacological strategies aimed at decreasing adverse effects of air pollution on cardiovascular system.

Keywords: Air pollution, Atherosclerosis, Cardiovascular diseases

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Introduction

Air pollution exposure is a major problem worldwide and has been linked to cardiovascular diseases (CVDs). Outdoor and indoor air pollution, which consists of a complex mixture of particulate matter (PM), gases (e.g., carbon monoxide [CO], ozone [O_3], nitrogen dioxide [NO_2], sulfur dioxide [SO_2]), is increasingly recognized as an important determinant of CVDs.[1-3] PM is described as a mixture of suspended particles that vary in chemical composition and size.[1] There is increasing evidence that exposure to air pollution is not only linked to pulmonary diseases, but also mainly to CVDs.[2-4]

Many conditions predispose to death from CVDs, particularly coronary artery disease (CAD), and include hypercholesterolemia,[5] hypertension,[6] a thrombotic tendency,[7] the postmenopausal state,[8] and ventricular arrhythmias.[9] It is reported that sudden death is usually the first and only manifestation in about 20% of patients who present with CAD[10] and about 75% of patients with myocardial infarction die outside the hospital.[11] This suggests that treatment is not available for many patients, and the focus should be to prevent the development and progression of CVDs.

Previous research have shown that gaseous pollutants (e.g., CO, NO_2) and toxic substances present in fine PM (e.g., black carbon, primary and secondary aerosols, metals) can cross epithelium of airway following inhalation, reaching the vasculature, and induce the production of proinflammatory cytokines and reactive oxygen species.[12] The effects produced by these air pollutants might subsequently lead to hypertensive responses and changes in autonomic cardiac control.[13]

The objective of this article is to consider a number of different air pollutants found either outdoor or indoor, such as gaseous pollutants and PM, associated with detrimental cardiovascular effects. Specifically, this study would review the current information on

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the effects of pollution exposure on cardiovascular system and the different mechanisms of air pollution-induced cardiotoxicity. It is expected that this review would provide a better understanding of the harmful cardiovascular effect induced by air pollution exposure, as well as their mechanisms of actions, and such information would be of use to researchers, healthcare providers and regulatory agencies, and could also be used by policy makers to determine acceptable levels of air pollution and to design ways to minimize the harmful cardiovascular effects of air pollutants on the body. In addition, elucidation of the physiological and molecular mechanisms of air pollution-induced cardiotoxicity might become an essential target in developing the novel pharmacological strategies aimed at decreasing the adverse effects of air pollution on cardiovascular system.

Outdoor/Indoor Air Pollutants and Associated Cardiovascular Effects

Certain environmental air pollutants are of special interest since they are associated with increased morbidity, hospitalization,[14] and mortality due to CVD.[2,3] In the United States, the six commonly found air pollutants are particle pollution (often referred to as PM), ground-level O_3, CO, SO_2, NO_2, and lead.[1] Worldwide, the air pollutants of concern include PM ("fine particles" [$PM_{2.5}$ < 2.5 μm], and "coarse particles" [$PM_{10\ to\ 2.5}$]), ground-level O_3, CO, SO_2, NO_2, lead, cigarette smoke, and carbon disulfide (CS_2).

Particulate Matter Air Pollution

PM is a mixture of particles that can adversely affect human health and includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. It is reported that the size of PM is directly linked to their potential for causing health-related problems. The United States Environmental Protection Agency (EPA) is mainly concerned about particles that are 10 μm in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can cause harmful effects on the lungs and heart. EPA groups particle pollution into two categories: fine PM and coarse PM.[1]

Fine particulate matter ($PM_{2.5}$)

Sources of $PM_{2.5}$

There are both outdoor and indoor sources of fine particulates (PM with an aerodynamic diameter less than 2.5 μm [$PM_{2.5}$]). Particles in the $PM_{2.5}$ size range are commonly found in smoke and haze and are of particular health concern since they are able to travel deeply into the respiratory tract, reaching the lungs and can also affect the heart. Throughout the world, the major sources of fine particles primarily are from human combustion of fossil fuels from different outdoor activities, such as from car, truck, bus, and off-road vehicle (e.g., construction equipment, snowmobile, locomotive) exhausts, other operations that involve the burning of fuels such as wood, heating oil, or coal, as well as natural sources such as forest and grass fires. $PM_{2.5}$ is also produced by common indoor activities, and such indoor sources of fine particles include tobacco smoke, cooking (e.g., frying, sautéing, and broiling), burning candles or oil lamps, and operating fireplaces and fuel-burning space heaters (e.g., kerosene heaters). Fine particles can also be emitted from the reaction of gases or droplets in the atmosphere from sources such as power generation plants.[1]

Cardiovascular effects of $PM_{2.5}$

Particles in the $PM_{2.5}$ size range are of particular health concern because they can reach the smaller airways and alveoli.[1] Scientific studies have linked increases in daily $PM_{2.5}$ exposure with increased cardiovascular morbidity and mortality. Exposure to ambient air-borne PM of < 2.5 μm ($PM_{2.5}$) is associated with increased incidences of specific acute CVDs, such as myocardial infarction, ischemic stroke, heart failure, cardiac arrhythmia, atrial fibrillation,[15] as well as peripheral arterial and venous diseases.[16] It is reported that constituents of ambient particulates from traffic emissions were more toxic than those from other sources.[17] Multiple studies have found associations between decreased heart rate variability (HRV) and elevated blood pressure and exposure to fine particulates ($PM_{2.5}$).[18] It is reported that short-term exposure to traffic-derived fine particulate air pollution is associated with acute cardiovascular events.[19]

Mechanism of action of $PM_{2.5}$ in cardiovascular disease

Several mechanisms have been reported for PM air pollution-associated cardiovascular effects, including inducing systemic inflammation, oxidative stress, increased blood coagulability, and autonomic and vascular imbalance.[20] Kampfrath *et al.*[20] investigated the molecular mechanisms by which $PM_{2.5}$ mediates inflammatory responses in a mouse model of chronic exposure. Their findings suggest that $PM_{2.5}$ triggers an increase in oxidized phospholipids in lungs that then mediates a systemic cellular inflammatory response through Toll-like receptor 4 (TLR4)/NADPH oxidase-dependent mechanisms.

Coarse particulate matter ($PM_{10-2.5}$)

Sources of $PM_{10-2.5}$

In contrast to fine particles which typically originate from combustion and photo-chemical processes, coarse

particles [PM with aerodynamic diameter between 2.5 and 10 μm ($PM_{10-2.5}$)] are mainly derived from processes such as mechanical grinding in industry and transportation, windblown dust, and agricultural activities; PM deposit preferentially in the upper and larger airways.[1]

Cardiovascular effects of $PM_{10-2.5}$

The findings from research on the health effects of coarse particles ($PM_{10-2.5}$) have been mixed.[21] Previous research has found associations between daily PM_{10} concentrations and cardiovascular mortality in the Coachella Valley, a desert resort and retirement area east of Los Angeles, California.[22] Another study[23] concluded that after adjustment for $PM_{2.5}$, there were no statistically significant associations between coarse particulates and hospital admissions for cardiovascular and respiratory diseases.

Mechanism of action of $PM_{10-2.5}$ in cardiovascular disease

One of the plausible mechanisms providing explanations for associations between exposure to airborne PM and increased risks of cardiovascular mortality is the alterations in cardiac autonomic control, assessed by changes in HRV. The relationship between. $PM_{10-2.5}$ and CVD is still controversial. Previous studies[24] found no relationship between $PM_{10-2.5}$ and changes in HRV; however, it was reported that those investigations took place in urban areas with low $PM_{10-2.5}$ levels. In a separate study, Lipsett *et al.*[25] examined the impact of PM on HRV in an area where $PM_{10-2.5}$ predominates, and found that elevated levels of ambient coarse particles ($PM_{10-2.5}$) may adversely affect HRV in older subjects with CAD.

Ground-Level Ozone Pollution (or Smog)

Sources of ground-level ozone

O_3 is described as a colorless gas molecule consisting of three atoms of oxygen, highly reactive and with a high oxidizing power. Where O_3 forms determines whether it is beneficial or harmful to health. In nature, O_3 forms at high altitude layers, that is, the so-called "ozonosphere" (15-60 km) forming a protective layer and is regarded as good O_3. This protective layer shields from the sun's harmful ultraviolet rays. Unfortunately, human-created chemicals are destroying this beneficial protective layer of O_3. In contrast to good O_3 layer, O_3 near ground level is a harmful pollutant and is called bad O_3. In lower atmosphere layers known as troposphere (<15 km high from the ground), O_3 formation is induced, especially during the summer when ultraviolet light in sun radiations triggers a chemical reaction with precursor chemical pollutants emitted by motor vehicles, thermoelectric plants, and industrial sources. These precursor pollutants are composed of nitro compounds like NO_2 and volatile organic hydrocarbons (VOC) like terpenes.[26]

Cardiovascular effects of ground-level ozone

Ground-level O_3, a major component of urban smog, is one of six air pollutants that the United States EPA have determined as likely to cause human health problems. Breathing ground-level O_3 can result in a number of harmful health effects. Many epidemiologic studies have shown that there is an association between PM and O_3 and the increased incidence of cardiovascular morbidity and mortality.[27] Data on the cardiovascular effects of ground-level O_3 is mixed. Although a positive association between O_3 and ischemic heart disease was found in Helsinki, Finland,[28] no associations were found in studies conducted in Tucson, Arizona,[29] London, UK,[30] and Edinburgh, Scotland.[31]

Mechanism of action of ground-level ozone in cardiovascular disease

O_3 has a high oxidizing power, and reacts with biomolecules to form ozonides and free radicals. In the body, this reaction triggers an inflammatory response that conveys increased systemic oxidative stress, which has both pulmonary and cardiovascular effects. According to Srebot *et al.*,[26] there is a possibility that pulmonary oxidant stress mediated by PM and/or O_3 exposure can result in downstream perturbations in the cardiovasculature, as the pulmonary and cardiovascular systems are intricately associated. Several mechanisms of cardiotoxicity have been observed and associated to ground-level O_3 exposure including modification of endothelial function and vascular vasomotricity, and alterations in autonomic control of cardiac frequency, activation of systemic inflammatory response mediated by cytokines and, increase of oxidative stress.[32-35] In a randomized, double-blind, crossover chamber study by Brook *et al.*,[27] it was found that O_3 can influence macrovascular diameter and tone. These researchers showed that inhalation of fine particulate air pollution and O_3 causes acute arterial vasoconstriction in healthy adults.[27] In one study conducted in the nursing home in Mexico, it was found that ambient levels of $PM_{2.5}$ and O_3 can reduce the high-frequency component of HRV and that patients with underlying arterial hypertension are particularly susceptible to this effect.[31] In another study, Gold *et al.*[36] suggested that both particulate and O_3 pollution may lead to short-term autonomic imbalance, reflected by changes in heart rate and HRV. It is reported that O_3 exposure mediates an inflammation response and increased oxidative stress in the cardiovascular system. *In vitro* studies[33] using peripheral human blood mononuclear cells have shown that a significant relationship exists between O_3 and increased lipid peroxidation and protein thiol group content. Studies using an animal model found that O_3 exposure causes increased systemic oxidative stress.[37]

Nitrogen Dioxide Air Pollution

Sources of nitrogen dioxide

NO_2, a suffocating, brownish gas, is predominantly derived from the oxidation of NO, the major outdoor source of which is combustion emissions, mainly from motor vehicles and stationary combustion sources such as electric utility and industrial boilers. NO_2 exposure indoors is from sources such as unvented combustion appliances.[1]

Cardiovascular effects of nitrogen dioxide

Harmful health effects from NO_2 may potentially result from NO_2 itself or its reaction products such as O_3. NO_2, an important air pollutant in the developed countries is positively associated with cardiovascular morbidity, hospitalization, and mortality. Research has shown that the concentration of NO_2 is associated with daily hospital emergency transports for ischemic heart diseases such as angina pectoris and myocardial infarction,[38] as well as for subsequent cardiac insufficiency and arrhythmia. Previous studies have shown that an interquartile range increase in NO_2 is associated with an increase of 6.1% of cardiovascular mortality.[39] It is reported that the cardiovascular effects of NO_2 are mainly observed in patients with CVDs aged 65 years or older who have high risks of atherogenesis.[40]

Mechanism of action of nitrogen dioxide in cardiovascular disease

Takano *et al*. demonstrated that daily exposure to NO_2 air pollution near ambient levels (0.16 ppm) enhances atherogenic lipid metabolisms primarily in the otsuka long-evans tokushima fatty (OLETF) rats, but less in the long-evans tokushima otsuka (LETO) rats. These researchers concluded that NO_2 air pollution near ambient levels is an atherogenic risk primarily in obese subjects.[41]

Sulfur Dioxide Air Pollution

Sources of sulfur dioxide air pollution

SO_2 is considered a toxic gas in air pollution and is described as a highly irritating, colorless, soluble gas with a pungent odor and taste. SO_2 is generally found at considerably lower concentrations in indoors compared with outdoor. Indoor sources of SO_2 include the use of kerosene space heaters.[42] Outdoor sources of SO_2 include burning of fossil fuels (coal and oil), combustion of sulfur-containing fuels, especially in power plants and diesel engines, and smelting of mineral ores (aluminum, copper, zinc, lead, and iron) that contain sulfur. Oxidation of SO_2 results in formation of sulfur trioxide, which, as a result of its strong affinity for water, can be rapidly hydrated to form sulfuric acid.[43]

Cardiovascular effects of sulfur dioxide air pollution

Sunyer *et al*.[44] reported the association of daily SO_2 air pollution levels with hospital admissions for CVDs in Europe. Their results suggest that SO_2 pollution may play an independent role in triggering ischemic cardiac events.[44]

Mechanism of action of sulfur dioxide in cardiovascular disease

Blood viscosity has been linked to severity of CVD[45] and has been found to increase in association with increased levels of ambient total suspended particles and SO_2.[46] Although SO_2 is considered to be toxic and detrimental to human health, recent studies suggest that SO_2 might be an endogenous gaseous signaling molecule involved in the regulation of cardiovascular functions.[47]

Lead Air Pollution

Sources of lead air pollution

Lead enters the body when a person inhales particles of lead that are suspended in the air. Lead is a naturally occurring element and it does not go away over time, unlike most pollutants. It is reported that the United States eliminated lead from gasoline and paints, a change that significantly reduced lead in air pollution in the United States, cutting it by 98% by 2002.[48] However, most of the lead that entered the air in the past remains in the environment, especially in the soil near major roadways.[49] A major indoor source of lead is old paint found in homes built before 1978.[50] Additionally, lead-contaminated soil and dust tracked indoors from outside also contribute to indoor lead pollution.[48]

Cardiovascular effects of lead air pollution

The cardiovascular effects of lead exposure includes elevation of blood pressure and hypertension[51] Other impacts of lead exposure on CVD include an increased incidence of clinical cardiovascular end points such as coronary heart disease (CHD), stroke, and peripheral arterial disease,[52] as well as other cardiovascular function abnormalities including left ventricular hypertrophy and alterations in cardiac rhythm.[53] Studies have shown that the effects of lead poisoning may continue after the source of exposure has been eliminated.[53]

Mechanism of action of lead air pollution in cardiovascular disease

It is reported that chronic exposure to low lead levels results in arterial hypertension that persists long after the cessation of lead exposure.[54,55] The potential mechanisms explaining a link between cardiovascular effect and environmental lead exposure include enhanced oxidative stress,[56] stimulation of the renin-angiotensin system,[57]

and down-regulation of nitric oxide[58] and soluble guanylate cyclase.[59] These biological mechanisms could lead to increased vascular tone and peripheral vascular resistance.[54] Research has shown that chronic lead exposure promotes atherosclerosis in experimental animals.[60] Among US adults, increased blood lead levels were associated with an increased prevalence of left ventricular hypertrophy.[61]

Carbon Monoxide Air Pollution

Sources of carbon monoxide pollution

CO is a colorless, tasteless, odorless, and highly toxic gas produced by incomplete burning of hydrocarbons in fuels.[62] Poisoning with CO is an important cause of accidental and intentional injury throughout the world. There are many indoor sources of CO including poorly installed and maintained heating systems, charcoal grills and hibachi pots that are used indoors, gas kitchen stoves that are used for heating, water heaters, and automobile exhaust.[63] The principal outdoor source of CO pollution in most large urban areas are automobiles. Other sources of CO include cigarette smoke, human and animal respiration, industrial processes, and burning of fossil fuels.[64]

Cardiovascular effects of carbon dioxide pollution

Exposure to CO has been implicated in the process of atherosclerosis. Evidence from human studies has shown that CO can exacerbate ischemic heart disease.

Mechanism of action of carbon monoxide pollution in cardiovascular disease

The predominant mechanism by which CO causes heart disease is through production of hypoxia. CO typically affects oxygenation of tissue due to carboxyhemoglobin (COHb) production, with consequent adverse to cardiovascular effects. The harmful effects of CO are more profound in the myocardium than in peripheral tissues because of very high oxygen extraction by the myocardium at rest.[65]

Cigarette Smoke

Sources of cigarette smoke pollution

Cigarette smoke consists of many chemicals, including nicotine, the addictive substance of cigarette smoke,[66] tar or particulate phase with its many carcinogens, and gaseous compounds including CO.[67]

Cardiovascular effects of cigarette smoke pollution

Cigarette smoking is a well-established risk factor for CVD in both men and women. There are a number of clinical atherosclerotic syndromes that are associated with cigarette smoking, including stable angina, acute coronary syndromes, sudden death, and stroke. It is reported that smokers who inhale deeply are likely to have an increased risk of both symptomatic peripheral arterial disease and abdominal aortic aneurysm.[68] Epidemiological evidences have clearly shown that cigarette smoking in both men and women increases the incidence of myocardial infarction and CAD.[69]

Mechanism of action of cigarette smoke in cardiovascular disease

It is reported that specific environmental toxins (such as tobacco smoke) introduced through the lungs can initiate and/or accelerate CVD development.[70] Although there is clear evidence linking cigarette smoke exposure with CVD, the exact components of cigarette smoke and the mechanisms involved in cigarette smoking-related cardiovascular dysfunction have not been clearly elucidated.[71] The effect of CO in cigarette smoke on atherothrombotic disease has been controversial. In one study, it was reported that CO could be responsible for smoking-related cardiovascular alterations.[72] In another study, it was found that CO from cigarette smoke was an unlikely cause for atherosclerosis or thrombus.[73] In studies using experimental models, it was demonstrated that polycyclic aromatic hydrocarbons (PAHs) present in the tar fraction of cigarette smoke have accelerated atherosclerosis.[74] It is reported that although the contribution of nicotine in cardiovascular morbidity and mortality induced by cigarette smoking is uncertain, nicotine has a well-established acute and chronic cardiovascular effects, principally through sympathetic activation.[75]

Biomass Smoke

Sources of biomass smoke pollution

Indoor air pollution resulting from solid fuels, principally biomass and coal, has been ranked as one of top 10 environmental risk factors of global burden of disease by the World Health Organization.[76] Studies have shown that biomass burning, especially wood, contribute to outdoor pollution.[77] In the developing countries, organic materials such as wood, dung, or charcoal (biomass fuel) are burned and used for cooking, home heating, and lighting.[78] It is reported that cooking or heating with biomass fuels in stoves or fireplaces vented to the outdoors (airtight stoves) produces high indoor air pollution. Studies from China showed that solid fuel use for cooking and heating are important activities contributing to indoor air pollution.[79]

Cardiovascular effects of biomass smoke pollution

Biomass fuel-combustion smoke have been associated with adverse health effects.[80] It is reported that biomass

fuel represents a considerable risk to cardiovascular health. The burning of solid fuels in the homes release several pollutants including respirable PM, PAHs, heavy metals, and many other organic pollutants,[81] which have been linked to CVDs. Studies have shown that exposure to PM can trigger acute cardiovascular events and accelerate chronic CVDs.[82] Studies conducted in China have shown that CVDs are expected to increase considerably in China, and the future trends in blood pressure, diabetes, total cholesterol, and body mass index may drive the CVD epidemic for the next 20 years.[83] Research has shown that biomass smoke in Guatemalan women increase diastolic blood pressure.[75]

Mechanism of action of biomass smoke air pollution in cardiovascular disease

The biological mechanisms associated with the toxic effects of in-home solid fuel exposure-related cardiovascular system are not completely understood, but the principal mechanisms may be linked to inflammation through the generation of reactive oxygen species and oxidative stress. It is reported that the potential biological mechanisms of action of biomass smoke include oxidative stress, promotion of inflammation with a systemic release of cytokines, and blood coagulation. In another study in China, it was shown that the use of biomass for cooking greatly increases exposure to PM, especially for the person performing the cooking. The PM released from biomass burning contains prooxidative organic hydrocarbons, such as PAHs, particularly in particle phase, that may cause oxidative damage to DNA and secretion of proinflammatory cytokines and chemokines that can result in detrimental cardiovascular effects. Exposure to PAH from cooking using biomass fuel is associated with oxidative damage to DNA, assessed by 8-hydroxy-2′-deoxyguanosine (8-OHdG), among workers in a Chinese restaurant.[84] Research has shown that chronic exposure to biomass smoke causes an increase in the number of leukocyte-platelet aggregates among Indian women,[85] and is recognized as a risk factor for thrombotic disease such as unstable angina,[86] myocardial infarction,[87] and stroke.[88]

Carbon Disulfide Air Pollution

Sources of carbon disulfide air pollution

CS_2 is described as a colorless, volatile, inflammable, and odorant liquid with a sweet aromatic odor. CS_2 is used mainly as an industrial chemical for the manufacture of rayon, cellophane, and carbon tetrachloride, as well as production of rubber chemicals and pesticides.[55] This implies that exposure to CS_2 occurs predominantly in the workplace. It is reported that workers in industrial plants that utilize CS_2 in their manufacturing processes have a high degree of exposure potential.[56] The release of CS_2 from industrial processes are almost exclusively to the air, and individuals in proximity to these sites may be exposed.[55] Inhalation by humans is regarded as the main route of CS_2 absorption in both occupational and environmental exposure.

Cardiovascular effects of carbon disulfide air pollution

A study by Hernberg *et al.*[89] suggested that workers exposed for at least 5 years to CS_2 showed an excess of deaths due to CHD. Previous studies reported the enhancing effects of CS_2 on atherosclerosis, including elevated serum cholesterol, phospholipids, and triglycerides in experimental animals, which was confirmed by biochemical studies.[90] Epidemiological studies have shown that chronic exposure to high concentrations of CS_2 may increase the risk of accelerated atherosclerosis and CHD.[91] In many studies, it is reported that there is increased prevalence of high blood pressure, electrocardiographic (ECG) abnormalities, clinical CHD, and lipid metabolism disturbances in workers exposed to CS_2 in varying degrees.[92] Multiple studies have shown an association between occupational exposure to CS_2 and CHD, even at lower exposures (30-120 mg/m^3).[93] However, in many other studies, there was no significant increase of the risk for CHD, especially at lower levels of exposure.[94] At low concentrations (under 30 mg/m^3) of CS_2 the question of CHD risk is still a controversial issue.[89] Ethnic differences were suggested to play a role. Research conducted in Japan, the Netherlands, and Yugoslavia found that that there was no evidence that CS_2 exposure affected CHD incidence.[89] These contradictory results suggest that CS_2 has coronary effects when predisposing factors to the development of CHD are present.

Mechanism of action of carbon disulfide air pollution in cardiovascular disease

In a study by Kotseva and De Bacquer,[95] it was shown that occupational exposure to CS_2 may increase total cholesterol and the risk of CHD. Their results also showed that there is a dose-response relationship between the level and duration of exposure and the prevalence of CHD. While the risk for CHD is increased in workers exposed to high CS_2 concentration for many years (CS_2 index ≥300), even a relatively modest exposure (CS_2 index <300) may increase serum cholesterol. The results imply that CS_2 may act by inducing disturbances in the lipid metabolism and acceleration of the atherosclerosis.[95]

Conclusion and Future Directions

Research linking air pollution to CVDs has grown substantially. This article has discussed the emerging role

of outdoor and indoor air pollutions in CVD. Previous research has shown associations between increased ambient air pollution and increased mortality, morbidity, hospitalization, and emergency department visits from CVD. Air pollution is a modifiable risk factor and understanding the harmful cardiovascular effects linked to it would enable preventive health measures to be taken, in order to reduce air pollution levels and associated diseases, and would be of further use to healthcare providers, regulatory agencies, and researchers. In addition, a better understanding of the biological mechanisms linking indoor/outdoor air pollution and CVD might become a vital target in developing novel pharmacological strategies focused on decreasing adverse effects of air pollution on cardiovascular system.

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