Indian Heart Journal 69 (2017) 425–429

Contents lists available at ScienceDirect

Indian Heart Journal

journal homepage: www.elsevier.com/locate/ihj

Editorial

Is smog innocuous? Air pollution and cardiovascular disease

ARTICLE INFO

Keywords:
Air pollution
Particulate matter
Cardiovascular risk

ABSTRACT

Air pollution is a significant environmental and health hazard. Earlier studies had examined the adverse health effects associated with short- and long-term exposure to particulate matter on respiratory disease. However, later studies demonstrated that it was actually cardiovascular disease that accounted for majority of mortality. Furthermore, it was not gaseous pollutants like oxides of nitrate, sulfur, carbon mono-oxide or ozone but the particulate matter or PM, of fine or coarse size ($PM_{2.5}$ and PM_{10}) which was linearly associated with mortality; $PM_{2.5}$ with long term and PM_{10} with short term. Several cardiovascular diseases are associated with pollution; acute myocardial infarction, heart failure, cardiac arrhythmias, atherosclerosis and cardiac arrest. The ideal way to address this problem is by adhering to stringent environmental standards of pollutants but some individual steps like choosing to stay indoors (on high pollution days), reducing outdoor air permeation to inside, purifying indoor air using air filters, and also limiting outdoor physical activity near source of air pollution can help. Nutritional anti-oxidants like statins or Mediterranean diet, and aspirin have not been associated with reduced risk but specific nutritional agents like broccoli, cabbage, cauliflower or brussels sprouts, fish oil supplement may help. Use of face-mask has been controversial but may be useful if particulate matter load is higher.

1. Great smog of London

Great smog of 1952 also known as Big Smoke was an episode of severe air-pollution that affected London in December 1952. It was really a collection of airborne particles, arising mostly from the use of coal, culminating in a thick layer of smog over the city, lasting 5 days (from 5–9 December 1952) and then dispersing as quickly as it came. As London was accustomed to heavy fogs, at the time it happened, there was no panic; it just seemed a denser and a longer standing fog, The only problem seemed to be such a low visibility that driving became impossible, all public transport ceased, ambulance service stopped functioning and all outdoor sporting events were called off. The fog even seeped indoors, resulting in the cancellation/abandonment of concerts and movies, since stage could not be viewed from the seats. Since that time there are several myths associated with air pollution (Table 1). However, the health aspects became apparent only after few weeks when medical statistics revealed that the smog had killed 4000 people.[1] As a matter of fact mortality remained elevated for months. The cause was attributed mostly to pulmonary system; asthma, respiratory tract infections: influenza, bronchopneumonia and purulent bronchitis but all this remained speculative because of faulty records. However, it was only more than 4 decades later that Harvard Six Cities study, with a large prospective cohort, for the first time convincingly demonstrated a definite relation between long term environmental pollution exposure and adverse health outcome. In over 8000 adults with 14–16 years of exposure, mortality rate was 26% higher in city with most pollution versus that with least pollution. Interestingly, this study made another surprising observation, it was not respiratory but rather cardiovascular (CVS) deaths which accounted for single largest cause of mortality, nearly half of all mortality (646 out of 1401). Furthermore, the risk for lung cancer and overall cardio-pulmonary mortality was increased by a similar ratio (but numerically numbers were higher for CVS).[2] The largest study to date, ACS Cancer Prevention II study enrolling nearly 500,000 individuals over a 16 year period also revealed that each 10 $\mu g/m^3$ increase in fine particulate matter (PM)contributed to increase in all cause, cardiopulmonary and lung cancer mortality of 4%, 6% and 8%, respectively.[3] Other hospital based studies also suggested specific association between air pollution and acute cardiac events.[4,5] Peter and co-workers provided the first evidence of association between air pollution and acute myocardial infarction (AMI).[6] It was Hoch and co-workers who found that it was exposure to traffic-related pollutants which were more co-relative with mortality than background level of pollutants within the city. Living near a major road was most strongly co-related to mortality in this study.[7] Among the specific CVS causes, 10 $\mu g/m^3$ increase in fine particulate matter contributed to 12% increased risk of CVS mortality, 18% increased risk of coronary artery disease (CAD) and 13% risk of cardiac arrhythmia, heart failure and cardiac arrest.[8] The short-term risks with acute exposure may even be higher. The NMMAPS study

http://dx.doi.org/10.1016/j.ihj.2017.07.016

Table 1
Myths associated with air pollution.

Myth	Reality
Fog/smog is innocuous	Smog has a definite adverse health effects
Health effects of air pollution are related to respiratory system	Majority of deaths related to pollutants are due to cardiovascular causes
Gaseous pollutants are major causes of health effects	Particulate matter in the air are most strongly related to health effects
The health effects are instantaneous	Health effects are both instantaneous and some occur after a lag period

conducted in 50 million individuals spread over 20 largest cities of US revealed that 10 $\mu g/m^3$ increase in coarser PM contributed to 21% increase in all-cause mortality and 31% increase in cardiopulmonary mortality.[9] Air Pollution and Health: a European Approach (APHEA-2) study conducted in another 43 million individuals in 29 European cities revealed an even more robust association between short term exposure and health effects. For each 10 $\mu g/m^3$ increase in coarse PM, daily mortality increased by 0.6% and CVS mortality by 0.7%.[10] Furthermore, this study went on to show that this increased mortality was not due to mere harvesting (temporal displacement of mortality or advancement of mortality by a few days) because after a lag period of 40 days this increase in CVS mortality was even more pronounced - actually more than doubled (1.97%).[11] Again even with short term exposure, direct association has been found with CAD, arrhythmia and heart failure, an increased rates of hospitalization: 0.8% increase for heart failure and 0.7% increase for CAD. In addition increased risk for AMI, implantable cardioverter defibrillator (ICD) discharges myocardial ischemia on stress testing, elevated systolic blood pressure and ischemic stroke have also been demonstrated.[12] In the developing world Beijing, China issued a first "red alert" when air pollution surpassed a level of 200 parts per million of fine particulates (referred to as $PM_{2.5}$) for at least three days on a four-tier index that catalogs air pollutants. The Great Smog of Delhi marked the worst period of bad air quality in New Delhi and adjoining areas in the National Capital Territory of India (between 1 and 9 November 2016). The pollution was reputed to be even worse than the London smog.

2. Mechanism of cardio-toxicity of air pollutants

Currently, combustion of fossil fuel, whether in industrial applications and power plants or exhaust from motor vehicles (airplanes, cars, trucks, or ships) account for the majority of pollution at least in developed countries. The emissions include gases; nitric oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO) or sulfur dioxide (SO_2), PM (both solid and liquid) like carbon black, organic carbon, even transition metals and volatile and semi-volatile organic compounds such as benzene, toluene, xylene, and aromatic hydrocarbons. However, as far as health hazards are concerned, while several gaseous pollutants, SO_2, nitrogen oxides, CO, Ozone (O_3) have been implicated to some extent, it is the PM which is the major culprit and has been co-related to total and CVS mortality. Particulate matter is of two types; fine PM – with particle median aerodynamic diameter $<2.5\ \mu m$ called $PM_{2.5}$ and coarse PM – with particle median aerodynamic diameter $<10\ \mu m$ called PM_{10}. Short-term mortality is co-relative of PM_{10} while long term mortality is related to exposure to $PM_{2.5}$. Particulate matter can be directly toxic to circulatory system (soluble components of $PM_{2.5}$ can cross respiratory epithelium into systemic blood stream) but more commonly affects the CVS indirectly. It may incite pulmonary and systemic oxidative stress, resulting into inflammation. The circulatory inflammation (even without significant lung toxicity) may serve as the initiator of a whole cascade of events culminating in alterations in blood rheology and pro-thrombotic effects (increased fibrinogen, enhanced platelet aggregation), alteration in cardiac autonomic system (blunting of cardiac parasympathetic system) leading to rhythm disturbances, endothelial dysfunction leading to vascular spasms and plaque disturbance in short-term and atherosclerosis in long term. The PM_{10} could readily penetrate and deposit in the extra-thoracic and trachea-bronchial tree, while $PM_{2.5}$ can reach the small airways and alveoli. Generally, $PM_{2.5}$ are derived from combustion sources including vehicular exhaust and constitute fine particles like nitrates and sulfates while PM_{10} are derived from natural sources (forest fires, bio-aerosol – endotoxins, fungal spores, pollen, windblown soil), and occupational exposure (grinding, smelting, etc.). Recently a third type of particles have also been described, the ultra-fine particles (UFP) ($<0.1\ \mu m$). They can penetrate deeper into the lungs and even directly enter the bloodstream. They arise from emissions of factory chimneys (smoke stacks) or exhaust from trucks (tail pipes), quickly coalesce together, absorb water, organic material and other gases to grow large to reach a particle size in the range of $PM_{2.5}$. Sulfur dioxides is derived from sulfur containing fuels like diesel, power plants, mining processes and kerosene space heaters but also from forest fires. It can cause toxicity by forming particulate sulfates. Diesel exhaust particles are known to increase interleukin-8 and thus provoke inflammatory cascade. Increased SO_2 levels increase fibrinogen levels. Nitrogen oxides are derived primarily from combustion of fossil fuel including vehicular exhaust and industrial processes. The major problem associated with nitrates is that they can readily form particulate nitrates. Ozone is the predominant component of photo-chemical smog. It can be sourced to vehicular exhaust and industrial processes, acted upon by UV radiation (nitrogen oxides and reactive hydrocarbons). It can induce direct oxidation of both pulmonary and systemic vasculature, resulting in inflammation. It is also known to provoke arterial vasoconstriction. Carbon monoxide derived by incomplete combustion of carbon based fuel; vehicular exhaust, coal combustion, residential wood burning and tobacco smoking acts as a direct toxicant. Both nitrogen oxides and CO are known to impair ICD discharges.[12]

3. Types of studies

There are three types of studies on air pollution

1. Time series or case-crossover studies which are hospital based and evaluate end-points such as daily total mortality, CVS mortality or hospital admissions.
2. Panel studies with repeated measures of clinical endpoints such myocardial revascularization or arrhythmias documented by ECGs, Holter monitors and ICD or even potential markers of arrhythmic risk including changes in myocardial repolarization and altered heart rate variability (HRV).
3. Prospective follow-up studies of cohort of subjects.

The largest body of evidence comes from hospital based studies which provide a statistical link between air pollution and end-points on a short term basis. On the other hand prospective follow-up studies are useful to determine temporal link of associations and determine long term risks. Panel studies are useful to identify link with individual components like arrhythmias.