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Particulate matter air pollution and cardiovascular disease

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ABSTRACT

Particulate matter air pollution, both indoor and outdoor, although traditionally causally associated with pulmonary disease, is now being increasingly implicated in cardiovascular disease and mortality. The rapid growth of many developing countries, with an explosive influx of motor vehicles, has greatly increased the ambient air pollution in several well populated cities, Beijing and Delhi are glaring examples. A review of published data on the associated increase in particulate matter air pollution, indicates that this 'developmental growth' is directly related to a steady increase in diseases and death. Indoor air pollution also continues to be a growing silent killer. Environmental particulate matter pollution has thus become a significant preventable health hazard. A major step towards its prevention is increased awareness, and this brief review is aimed at highlighting the deleterious effects of particulate air pollution, and its dismal effects, especially on the cardiovascular system.

Key words: air pollution, atherosclerosis, cardiovascular diseases, particulate matter, household air pollution, ambient air pollution

Abbreviations: CVDs: Cardiovascular Diseases; PM: Particulate Matter; WHO: World Health Organization

1. INTRODUCTION

Air pollution is detrimental to our health (Brunekreef et al, 2002; Lai et al, 2013) and is a major preventable environmental risk (WHO, 2012; Lim et al, 2010). It is estimated that in 2008, nearly 1.3 million deaths in the world were related to ambient air pollution and two million due to household air pollution. These numbers climbed dramatically, and in 2012, with nearly seven million deaths due to combined ambient and household air pollution. (WHO2) The numbers unfortunately, continue to climb (WHO 4).

The major negative impact of particulate air pollution is on respiratory function (Hoek et al, 1998; Karl-Christian et al, 2016) and respiratory diseases (Paulin et al, 2016). These include chronic obstructive pulmonary disease (Faustini et al, 2013l Kelly et al, 2011), asthma (Guarnieri et al, 2014; Zhang et al, 2015; Kelly et al, 2011; Karakatsani et al, 2012), and lung cancer (Vineis et al, 2006; Sax et al, 2013; Chen et al, 2015). Besides lung cancer, air pollution has also been linked to an increase in head and neck cancers, nasopharyngeal cancers (Wong et al, 2014), and urinary tract cancers (Castano-Vinyals et al, 2008). Adverse effects of air pollution on the nervous system are also well known (Genc et al, 2012), and a causal relationship has been implicated in diseases such as Parkinson's disease, Alzhiemer's disease, multiple sclerosis and stroke (Elbaz et al, 2008; Lauer et al, 2010; Mateen et al, 2011; Calderon-Garciduenas et al, 2004). It also affects the digestive system (Beamish et al, 2011), including nonspecific abdominal pain (Kaplan et al, 2009; Kaplan et al, 2012), appendicitis (Kaplan et al, 2013), and irritable bowel syndrome (Marynowski et al, 2015). The noxious particles are removed from the nasopharyngeal compartment and airways, where they are deposited, and subsequently swallowed, resulting in the digestive system ailments (Lippman et al, 1980). A connection with diabetes mellitus has also been noted (Zanobetti et al, 2001; Bhatnagar et al, 2009; Andersen et al, 2012; Rao et al, 2015). Air pollution may also incite skin diseases, such as alopecia, inflammatory reactions, increased aging and skin cancer (Kim et al, 2016). Long-term ambient air pollution exposure is associated with a significant increase in all-cause mortality (Zanobetti et al, 2009; Carey et al, 2009). The elderly (Pope, 2000) and those of lower socioeconomic status, especially women and children, are more vulnerable to the toxic effects of air pollution (Pope et al, 2002).

Besides ambient air pollution, indoor air pollution also poses a major health risk to over 3 billion people who use solid fuels such as wood, charcoal, coal, dung and crop wastes to cook and heat their homes (WHO3). Many use open fires or traditional stoves which release high levels of indoor particulate matter and carbon monoxide (Spengler et al, 1983) – putting women and young children at a major risk of premature ailments and premature death (Viegi et al, 2004). These diseases include acute respiratory infections (Smith et al, 2000) bronchial asthma, (Milligan et al, 2016), obstructive lung disease (Kelly et al, 2011), and lung cancer (Mumford et al, 1987; Bruce et al, 2000). Its impact is particularly deleterious to unborn or very young children, where indoor pollution also increases low birth weight, increased infant and perinatal mortality, besides the diseases mentioned above (Mavlankar et al, 1991; Wang et al, 1997; Bobak, et al, 1999; Loomis et al, 1999). WHO estimates that 4.3 million people a year die from the exposure to household air pollution (WHO4).

The role of air pollution as a risk factor for cardiovascular disease is well documented – however it is not well appreciated (Ruckerl et al, 2006; Hassing et al, 2009; Watson et al, 2012; Gold et al, 2013). According to the WHO, (WHO5) outdoor air pollution was responsible for deaths as follows: Ischemic heart disease: 40%, stroke: 40%, chronic obstructive pulmonary disease: 11%, lung

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cancer 11% and lower respiratory lung infections in children: 3%. Indoor air pollution related deaths were as follows: stroke: 34%, ischemic heart disease: 26%, COPD: 22%, acute lower respiratory tract infections in children12% and lung cancer: 6%.

The major deleterious effects of air pollution on cardiovascular disease are increasingly being recognized (Ruckerl et al, 2006; Hassing et al, 2009; Watson et al, 2012; Gold et al, 2013). This article objectively looks at this association.

2. METHODS

A comprehensive literature search was carried out using the PubMed and PubMed Central database of the US National Library of Medicine, National Institutes of Health, on 'air pollution and cardiovascular diseases'. Air pollution was also interrogated on World Health Organization site. Additional studies were identified by searching bibliographies of reviews and were consulted, if relevant. Available scientific grey material was also reviewed.

3. RESULTS

'Air Pollution' revealed 59,768 citations dating back to 1930 on PubMed while there were 33,966 citations on PubMed Central. 'Air pollution and cardiovascular diseases' revealed 3,441 citations dating back to 1956 on PubMed. 'Air pollution and cardiovascular diseases' revealed 7,516 full length articles on PubMed Central.

4. DISCUSSION

Cardiovascular disease continues to be the number one killer in the world, resulting in 17.5 million deaths in 2012 (Heart, 2017). Its global death impact is expected to grow to more than 23.6 million by the year 2030. The main cardiovascular diseases (CVDs) include coronary artery disease, heart failure, stroke, cardiac arrhythmias and peripheral vascular disease. CVD's are also a leading cause of disability throughout the world, and exert extensive emotional and financial burden on individuals, families, societies and countries (Gaziano, 2007; Goyal et al, 2006). The risk factors for CVDs are well known (Fryar et al, 2012), and include hypertension (Kearney et al, 2006; Ikeda et al, 2012; Shashi K Agarwal, 2017a), diabetes mellitus (Ferrannini et al, 2012; Epstein et al, 1997; Mahler, 1990; Shashi K Agarwal, 2017b), hypercholesterolemia (Stamler et al, 1986; Neaton et al, 1992; Lavie et al, 2008; CTT, 2008), obesity (Mandal et al, 2008; Caballero, 2007; Marie et al, 2013), smoking (Teo et al, 2006; Mons et al, 2015; Huxley et al, 2011; Hurt et al, 2012), stress and anxiety (Rozanski et al, 1999; Lichtman et al, 2008), imprudent diet (Lichtenstein et al, 2006), and inactivity (Hakim et al, 1999; Manson et al, 1999; Jolliffe et al, 2001).

Air pollution is also emerging as a major risk factor for the development of CVDs. Air consists of a complex mixture of compounds in gaseous, liquid, and solid phases. This communication is focused on the particulate matter. Increasing evidence from clinical and epidemiological studies indicate that particulate matter less than 10 microm (<PM10) is detrimental for cardiovascular health (Poloniecki et al, 1997; Pope et al, 2002; Samet et al, 2000). Particulate matter in the environment of clinical concern is primarily divided into three categories according to their aerodynamic diameter: Coarse: PM10 – PM2.5; Fine: PM2.5 to PM1 and ultrafine: <PM1) Most studies have noted changes in clinical health with changes of a 10-µg/m3 elevation in fine PM in the ambient atmosphere (Pope et al, 2004). Coarse particles are usually generated from natural sources such as road dust, construction and demolotion work and agriculture dust (Manoli et al, 2002, Brook et al. 2010; Brunekreef and Forsberg, 2005). Although deposited mainly in the extrathoracic and upper tracheobronchial regions, they are not harmless (Brunekreef et al, 2005), especially for the cardiovascular system (Yeats et al, 2007; Zanobetti et al, 2009) A 10 µg/m3 change in daily PM10 is associated with an approximately 1% increase in mortality, (Bart et al, 1999). Fine particles emanate from combustion sources such as power plants, oil refinery and metal processing facilities, tailpipe and brake emissions, residential fuel usage, and wildfires. Although coarse particulate matter has also been implicated in causing increased cardiovascular disease, most studies show that PM25 plays the major causal role in cardiovascular ill effects (Pope et al, 2006). These particles show greater deposition in the deep lung and are taken up by alveolar macrophages and endothelial cells, (Mills et al, 2006; Nemmar et al, 2001) and have a stronger correlation with adverse health effects than PM10. According to WHO, fine particulate matter is responsible for about 16% of lung cancer deaths, 11% of COPD deaths, and more than 20% of ischemic heart disease and stroke (WHO3). The primary contributors to UFPs are tailpipe emissions from exhaust of motor vehicles, aircrafts, and marine vessels (Boris et al, 2008; Kim et al, 2002). These not only demonstrate a very high deposition in the alveoli, (Oberdorster et al, 2001) they may even be able to pass directly into the circulatory system, directly and thus spread all over the body, resulting in direct extrapulmonary damage (Nemmar et al, 2001; Nemmar et al, 2002; Oberdorstar et al, 2002), including systemic inflammation and progression of atherosclerosis and its related events (Brown et al, 2002; Franck et al, 2011; Valavanidies et al, 2008).

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WHO has defined guidelines for safe lower levels of particulate matter in 2005. For PM2.5, these are 10 µg/m3 annual mean and 25 µg/m3 24-hour mean and for PM10. 20 µg/m3 annual mean and 50 µg/m3 24-hour mean. No guidelines are available for ultrafine particles. (WHO3) Short term increase (measured over 24 hours) in PM10 particulate matter by 10-mircrom/m3 raises cardiac mortality by 0.31% (Dominici et al, 2003), while a similar increase in PM2.5 annual average exposure, increased cardiac mortality by 8% (Pope et al, 2002).

Particulate air pollutants often cause endothelial dysfunction and vasoconstriction (Brook et al, 2002, Barath et al, 2010; Mills et al, 2005), increase in blood pressure (Brook et al, 2009; Kubesch et al, 2015), heart rate (Peters et al, 1998), increased plasma viscosity (Peters et al, 1997), prothrombotic and coagulant changes (Pekkanen et al, 2000), systemic inflammatory (Salvi et al, 1888; Quay et al, 1998; Pope et al, 2004), and oxidative stress responses (Pritchard et al, 1996; Barregard et al, 2006; Miller, 2014) decreased heart rate variability (Gold, 2000; Magari, 2002), autonomic imbalance (Lee et al, 2014), and arrhythmias (Cakmak et al, 2014), increase in insulin resistance (Sun et al, 2009), and the progression of atherosclerosis (Suwa et al, 2002; Chen et al, 2005; Niwa et al, 2007).

A considerable epidemiological and clinical data confirms that both short term and long term exposure to air pollution is detrimental to human health. There are exacerbations of symptoms of cardiovascular diseases (Hoek et al, 2001; Peters et al, 2000; Peters et al, 2001; Pekkanen et al, 2002), and ischemic strokes (Hong et al, 2002; Tsai et al, 2003; Shashi K Agarwal, 2017c). There are increases in emergency room visits (Delfino et al, 1997; Schwartz et al, 1993) hospital admissions (Linn et al, 2000; Morris et al, 1995; Zanobetti et al, 2000; Sunyer et al, 2003, Dominici et al, 2006), and mortality related to coronary artery disease (Hassing et al, 2009; Simkhovich et al, 2009; Nawrot et al, 2011; Mustafic et al, 2012). There is worsening of heart failure, increase in heart failure hospitalizations and increased heart failure mortality (Shah et l;, 2013; Morris et al, 1996; Goldberg et al, 2003), Stroke hospitalizations and stroke related mortality is also higher in these patients (Maheswaran et al, 2003; Anderson et al, 2012; Maheswaran et al, 2012; Oudin et al, 2009). Patients dying of sudden cardiac death appear to do so more when ambient air pollution is high (Rosenthal et al, 2008; Sullivan et al, 2003). Overall, cardiovascular morbidity and mortality is increased (Brooke et al, 2004; Tofler et al, 2006; Analitis et al, 2006; Pope et al, 2004, Rich et al, 2005; Vedal et al, 2004; Metzger et al, 2007), and life expectancy is reduced.

The health related and economic benefits emanating from a reduction in ambient and household particulate matter pollution are potentially tremendous, especially in developing countries like India (Chowdhury et al, 2016).

5. CONCLUSION

Particulate air pollution is strongly associated with a host of medical ailments, including an increase in cardiovascular morbidity and mortality. A reduction in the particulate matter in the ambient and household air decreases disease exacerbations, emergency room visits, hospitalizations and premature death. Policies that are geared towards mandated elimination or reduction of sources of ambient and indoor particulate matter need to be implemented. In the interim, raising public awareness of the significant deleterious health consequence of particulate air pollution, and close monitoring and adequate warnings of present time dangerous levels, will greatly help improve the quality of life for people all over the world.

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CONFLICT OF INTEREST

None

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