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## Mini-Review

# A systematic review of air pollution as a risk factor for cardiovascular disease in South Asia: Limited evidence from India and Pakistan

S.S. Yamamoto<sup>a,\*</sup>, R. Phalkey<sup>a</sup>, A.A. Malik<sup>b</sup><sup>a</sup> Institute of Public Health, University of Heidelberg, Heidelberg, Germany<sup>b</sup> Federal Postgraduate Medical Institute, Lahore, Pakistan

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## ABSTRACT

Cardiovascular diseases (CVD) are major contributors to mortality and morbidity in South Asia. Chronic exposure to air pollution is an important risk factor for cardiovascular diseases, although the majority of studies to date have been conducted in developed countries. Both indoor and outdoor air pollution are growing problems in developing countries in South Asia yet the impact on rising rates of CVD in these regions has largely been ignored. We aimed to assess the evidence available regarding air pollution effects on CVD and CVD risk factors in lower income countries in South Asia. A literature search was conducted in PubMed and Web of Science. Our inclusion criteria included peer-reviewed, original, empirical articles published in English between the years 1990 and 2012, conducted in the World Bank South Asia region (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka). This resulted in 30 articles. Nine articles met our inclusion criteria and were assessed for this systematic review. Most of the studies were cross-sectional and examined measured particulate matter effects on CVD outcomes and indicators. We observed a bias as nearly all of the studies were from India. Hypertension and CVD deaths were positively associated with higher particulate matter levels. Biomarkers of oxidative stress such as increased levels of P-selection expressing platelets, depleted superoxide dismutase and reactive oxygen species generation as well as elevated levels of inflammatory-related C-reactive protein, interleukin-6 and interleukin-8 were also positively associated with biomass use or elevated particulate matter levels. An important outcome of this investigation was the evidence suggesting important air pollution effects regarding CVD risk in South Asia. However, too few studies have been conducted. There is an urgent need for longer term investigations using robust measures of air pollution with different population groups that include a wider range of air pollutants and outcomes, including early indicators of CVD. These regions are facing burdens from increasing urbanization, air pollution and populations, generally weaker health infrastructure, aging populations and increased incidence of non-communicable diseases, including CVD. The extent to which the problem of air pollution and CVD will impact these countries will depend largely on the information available to inform policy and programs, which are still lacking, political will as well as social and economic development.

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## Introduction

Both indoor and outdoor air pollution is a growing problem, especially in developing countries (Smith, 2002). Of the deaths attributable to indoor air pollution, 64% occur in Asia and Africa, mainly due to the burning of biomass solid fuels (WHO, 2009k; Lim et al., 2012). Concerning environmental causes of ill health, exposure to household air pollution from solid fuels is the leading risk factor in terms of the attributable burden of disease in South Asia

(Lim et al., 2012). Additionally, the largely unregulated growth of urban areas particularly in Asia has led to unprecedented increases in vehicular traffic and industrial activity (Ostro, 2004; Su et al., 2011) such that some of the highest outdoor air pollutant levels globally can be found in these regions (Chung et al., 2011). Compounding the issue of air pollution is inadequate infrastructure, poor or non-existent emissions standards and regional instability (Pande et al., 2002).

Cardiovascular diseases are also major and growing contributors to mortality and morbidity in South Asia (Murray and Lopez, 1996; Nishtar, 2002; WHO, 2011; Lim et al., 2012). Between 1990 and 2020, ischemic heart disease is anticipated to increase by 120 percent for women and 137 percent for men in developing countries, compared with age-related increases of 30–60 percent in developed countries (Leeder et al., 2004). Cardiovascular disease

\* Corresponding author at: Institute of Public Health, University of Heidelberg, Im Neuenheimer Feld 324, 69120 Heidelberg, Germany. Tel.: +49 6221 56 36158; fax: +49 6221 56 36158.

E-mail address: [shelby.yamamoto@urz.uni-heidelberg.de](mailto:shelby.yamamoto@urz.uni-heidelberg.de) (S.S. Yamamoto).

**Table 1**  
Air pollution and cardiovascular disease burdens in South Asian World Bank countries compared to Germany and the United States.

Country	Outdoor air pollution Mean urban PM <sub>10</sub> µg/m <sup>3</sup>	Indoor air pollution Percentage of solid fuel-using households	Cardiovascular disease DALYs/1000 capita per year
Afghanistan	27	>95	8.1
Bangladesh	157	89	3.5
Bhutan	13	67	3.6
India	84	82	4.0
Maldives	54	43	1.8
Nepal	161	81	3.8
Pakistan	165	81	3.2
Sri Lanka	93	67	3.2
Germany	29	<5	3.9
United States	24	<5	3.4

WHO (2009e,d,f,g,h,i,b,c,a,j).

is currently the leading health problem in urban India. Furthermore, between 2000 and 2030, about 35 percent of all CVD deaths in India will occur among those aged 35–64, compared with only 12 percent in the United States and 22 percent in China. Thus, the economic impact of cardiovascular diseases in developing economies is much heavier than in developed countries, largely because working-age adults account for a high proportion of the CVD burden (Leeder et al., 2004).

Chronic exposure to air pollution is an established risk factor for morbidity and mortality from cardiovascular diseases (coronary heart disease (heart attacks), cerebrovascular disease (stroke), raised blood pressure (hypertension), peripheral artery disease, rheumatic heart disease, congenital heart disease and heart failure) (Smith, 2002; Brook et al., 2004; Pope et al., 2004). The exact mechanisms of the biological effects of air pollutants on the cardiovascular system are not completely known. One pathway could be via the lungs, through which pollutants then enter the circulatory system and reach critical organs. Exposure may also result in hematological and immunological changes that increase the susceptibility of people to cardiovascular problems or other conditions (Banerjee et al., 2012b). Mechanisms could be inflammatory, related to immune responses or the direct effects of free radicals on intracellular sources of reactive oxygen species.

The vast majority of studies on the air pollution and CVD are from developed countries (Brook et al., 2004; Pope et al., 2004; Su et al., 2011). The effects of air pollution on cardiovascular health has been less explored in developing Asian countries, despite the fact that they have comparable or higher outdoor air pollutant levels, greater biomass fuel use, which is indicative of higher levels of indoor air pollution (Balakrishnan et al., 2004; Fullerton et al., 2008), and comparable or greater CVD burdens than developed countries (Table 1) (Mohanraj and Azeez, 2004; Bruce et al., 2011; Dutta et al., 2011). This is a critical gap in our knowledge. Extrapolating findings from developed to developing countries is not likely to be useful as pollution levels, pollutants and sources are different (Cropper et al., 1997; Smith and Mehta, 2003) as well as dietary and other lifestyle factors. With this in mind, we aimed to assess the body of evidence available regarding air pollution and CVD in South Asia and identify existing research gaps and needs.

## Methods

We evaluated the available evidence from empirical studies regarding air pollution as a risk factor for cardiovascular disease in the World Bank South Asia region (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka). We focused on research conducted in these areas as less evidence exists regarding this issue in these countries, compared to other, more developed Asian countries like China, Taiwan and Japan (Su et al., 2011). Rising rates of CVD (Leeder et al., 2004) and air pollution

(Chung et al., 2011) also underlines the importance of building an evidence base to inform policy and develop mitigation strategies in these countries.

A literature search examining the effects of air pollution and cardiovascular disease was conducted using the databases PubMed and Web of Science. Inclusion criteria included peer-reviewed, empirical, original articles in English published between the years 1990 and 2012. The key search terms used were “air pollution” (indoor, outdoor or radioactive) and “cardiovascular diseases” (ischemic heart disease or coronary artery disease; cerebrovascular disease; aortic and arterial diseases including hypertension and peripheral vascular disease; congenital heart disease; rheumatic heart disease; cardiomyopathies; cardiac arrhythmias) (WHO, 2011) and each of the South Asian countries listed above. The search consisted of permutations and combinations of all keywords. Search algorithms in PubMed and Web of Science included at least one term from each of the abovementioned groups. Two researchers (SSY and RP) independently conducted the database searches between July and September, 2012, with an additional update of the literature in June, 2013.

This yielded 26 English language articles in PubMed and Web of Science (Fig. 1). Four additional articles were identified through other sources (i.e. snowballing). The removal of duplicates resulted in 28 articles. We excluded 12 articles on the basis of their titles and abstracts for the reasons that they were not from the World Bank South Asian region or did not examine the issue of air pollution and CVD. The remaining 16 articles were then assessed and our inclusion criteria applied. Of these, a further seven were excluded for not presenting original, empirical data or for failing to provide sufficient statistical information to enable assessment of the presented findings. The remaining nine articles were included in this review.

## Results and discussion

### Findings

Evidence regarding air pollution exposure and the risk of CVD in these South Asian regions is clearly lacking. Only nine empirical studies examined cardiovascular deaths, disease, symptoms, biomarkers or other indicators of CVD in relation to outdoor or indoor air pollution (Table 2). Nearly all of the studies examined in this review were from North and West India. Only one study was conducted in Pakistan. None were conducted in Afghanistan, despite the high burden of CVD, and none were conducted in Bangladesh, Nepal and Sri Lanka, which have high recorded ambient urban levels of PM<sub>10</sub> (WHO, 2009g,i,b). We also did not find any studies from either Bhutan or Maldives. In a systematic literature review on cardiovascular outcomes and short-term air pollution exposure in Asia, Su et al. (2011) discovered that nearly

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