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Review

Status of indoor air pollution (IAP) through particulate matter (PM) emissions and associated health concerns in South Asia

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HIGHLIGHTS

- Evaluation of PM associated IAP studies during 1990–2017 in South Asia.
- Systematic summary of PM levels in different indoor settings and personal exposure.
- Overview of IAP associated mortality and morbidity cases in South Asia.
- Cumulative hazard function of indoor PM personal exposure using Cox regression model.
- Prospects of IAP reduction strategies in South Asia.

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ABSTRACT

Exposure to particulate emissions poses a variety of public health concerns worldwide, specifically in developing countries. This review summarized the documented studies on indoor particulate matter (PM) emissions and their major health concerns in South Asia. Reviewed literature illustrated the alarming levels of indoor air pollution (IAP) in India, Pakistan, Nepal, and Bangladesh, while Sri Lanka and Bhutan are confronted with relatively lower levels, albeit not safe. To our knowledge, data on this issue are absent from Afghanistan and Maldives. We found that the reported levels of PM_{10} and $PM_{2.5}$ in Nepal, Pakistan, Bangladesh, and India were 2–65, 3–30, 4–22, 2–28 and 1–139, 2–180, 3–77, 1–40 fold higher than WHO standards for indoor PM_{10} (50 μg/m^3) and $PM_{2.5}$ (25 μg/m^3), respectively. Regarding IAP-mediated health concerns, mortality rates and incidences of respiratory and non-respiratory diseases were increasing with alarming rates, specifically in India, Pakistan, Nepal, and Bangladesh. The major cause might be the reliance of approximately 80% population on conventional biomass burning in the region. Current review also highlighted the prospects of IAP reduction strategies, which in future can help to improve the status of indoor air quality and public health in South Asia.

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1. Background

Indoor air pollution (IAP) through fine particulate matter (PM) is responsible for the death of more than a million people worldwide annually. These respirable particles with diameter $\leq$10 μm are also accounted for approximately 2.7% of global burden of diseases, which mainly include acute respiratory infections (ARI) and chronic obstructive pulmonary diseases (COPD) (Hetland et al., 2000). PM is basically generated in the indoor environment through the burning of conventional fuels such as coal, kerosene oil, domestic litter, dung, and crop residues in typical leaky stoves and open fires (Barnes et al., 1994). Worldwide, about 3 billion people are using conventional solid fuels, which is the highest ever number in human history (Chafe et al., 2015). According to previous reports, about more than 2.8 billion people are exposed to conventional solid fuel (SF) burning in developing countries. Further, it is also established that the households from South Asian Region (SAR) are predominantly exposed to alarming levels of PM in the form of respirable smoke release from consumption of biomass fuels in poorly ventilated homes (Hetland et al., 2000; Mitra, 2002).

In South Asia, major reported sources of indoor PM are anthropogenic activities *e.g.* burning of conventional fuels (wood, charcoal, animal manure, agriculture waste) and indoor smoking and fire (WHO, 2007b, 2009). Further, the major concerns of IAP in the region are increasing mortality rates of household females and infants as well as premature births (WHO, 2007b, 2009). During the year 2004, approximately 80% population was exposed to SF burning in SAR, which predicted that if the policies remain unregulated then almost 2.6 to 2.7 billion people will be exposed to unsafe biomass burning by 2030 (WHO, 2007b; Begum et al., 2009; WHO, 2009). Evidence suggested that the use of relatively cleaner fuels largely depends on their availability and affordability in the local markets. Due to recent poverty boost in South Asia, the considerably high proportion of population can't afford clean fuels, therefore, the utility of clean fuels have been reversed or slowed down (WHO, 2009).

In South Asia, most of the rural households are using typical mud stoves, which emit fine fractions of PM due to incomplete fuel combustion (Chowdhury et al., 2012b). These less efficient stoves are preferred because of cheap prices. Consequently, a high proportion of the population living in the rural areas exposed to malign indoor pollutants. Moreover, the main factors behind households' vulnerability to IAP are lack of protective measures, improper policy formulation, and unavailability of emission standards (Marcazzan et al., 2001). Therefore, under such circumstances, the inhalation of PM in indoor settings can induce hazardous impacts and prolonged indoor exposures can also cause cancer and other epidemics (Gharaibeh et al., 2010). High mortality and morbidity rates due to elevated levels of PM have already attracted the attention of researchers and regional organizations (Pant, 2008; Yamamoto et al., 2014). Lack of awareness among 80–90% households related to the harmful impacts of PM emissions has made this situation worse in the region (Diaz et al., 2007).

Persistence of PM in indoor settings also depends on various factors such as ventilation, insulation, building construction design, and building material. Primarily, it depends on the type of stoves, nature of fuels, exposure frequency, seasons, and lack of preventative measures (Taneja and Masih, 2008). In addition, the unplanned congested urban areas also affect the emission levels, transport, and fate of PM in the indoor settings (Lee et al., 2010). PM traces generate from burning and heating processes are mostly non-volatile, persistent, and remain structurally intact even after traveling long distances through the atmosphere. Another factor responsible for PM's persistence in the environment is their resistant nature to chemical transformation (Morawska and Zhang, 2002).

Indoor PM emissions are responsible for incidences of significant health hazards such as respiratory diseases (acute and chronic), lung malfunctioning, asthma, premature births, and elevated hospital visits throughout South Asia (Zaidi et al., 2011; Yamamoto et al., 2014). Recently, air pollution (indoor and outdoor) is listed as the world's largest single environmental health risk with the ever increasing association to the incidences of cardiovascular diseases and cancer (WHO, 2014; Baklanov et al., 2016). Children, females, and elderly people are the prone groups in the indoor settings and long-term PM exposure can weaken their immune system (Gurley et al., 2012; Salje et al., 2014). Moreover, patients with asthmatic, cardiovascular, and lungs diseases are more susceptible to IAP (Smith, 2000). Considering health consequences, $PM_{2.5}$ is more hazardous in comparison to PM_{10} because of the properties such as large surface area, high adsorption capacity, and deep penetration into the alveolar sacs (Hussain et al., 2011).