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Household (Kitchen) air pollution and its health effects and control measures

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Abstract
Worldwide, more than three billion people are dependent on the burning of solid fuel for cooking and heating of their houses. Incomplete combustion products emitted into the indoor air form a health threat, especially for women, young children and senior citizens. Air quality is also influenced on a local and global scale and the unsustainable harvesting of fuel wood leads to deforestation.
Household (Kitchen) environmental quality has a significant impact on public health and well-being. These hazards cause and exacerbate a variety of adverse health effects in humans, ranging from acute and chronic respiratory symptoms etc. This review is an attempt to explore effects of kitchen allergen exposure and focusing on household (kitchen) pollutants such as carbon monoxide and particulate matter ($PM_{2.5}$) due to combustion of solid fuel. Additionally, control measures are described and improvement of such harmful environmental conditions should be undertaken.

Keywords: environmental pollution, health effects, prevention

Introduction

Energy is considered as a key factor which determines the economic development in the entire sector of any region. Biomass energy is a prime requirement for meeting the domestic needs among the rural folk of developing countries. Sources for biomass energy are mainly derived from wood, agricultural residues and cow dung cakes. Most of the rural households in India use biomass for cooking and heating purposes. The biomass combustion emit huge amount of pollutants which causes harmful effects on environment and on human health.

Biomass has been used as a fuel since millennia. Until the mid-19th century, biomass dominated the global energy consumption. With rapid increase in fossil fuel use, share of biomass in total energy has declined steadily over a century (woods and Hall, 1994). Yet, biomass still contributes 14% of the world energy and 38% energy in developing countries.

National Family Health Survey (1992) reported that three-quarters of households use unprocessed biomass as their primary fuel for cooking food. Cooking smoke is a known risk factor for a number of respiratory diseases, such as acute respiratory infection, chronic obstructive lung disease and lung cancer. The mechanism by which cooking smoke can increase the risk of tuberculosis is, however, not well understood. It is plausible that cooking smoke increases the risk of tuberculosis by reducing the respiratory system, ability to resist infection by Mycobacterium tuberculosis or to resist the development of active tuberculosis in already infected persons.

Over 72 percent of all households in India and 90 percent of households in the country's poorer, rural areas use traditional solid fuels, such as crop residue, cow-dung, and firewood, to meet their cooking needs (Census of India 2001). The burning of solid fuels indoors in open fires or traditional cooking stoves results in high levels of toxic pollutants in the kitchen area. As such, the use of these fuels is considered a major risk factor for lung cancer as well as cardiovascular and respiratory disease (WHO 2002).

Worldwide, approximately 3 billion people rely on solid fuels for everyday cooking and heating, mostly in the form of biomass (wood, animal dung or crop wastes) but also coal (mainly in China) (Rehfuess *et al*., 2006) [39]. The use of solid fuels in poorly ventilated conditions results in high levels of indoor air pollution, most seriously affecting women and their children (Bruce *et al*., 2000) [10]. Indoor air pollution, smoking and occupational hazards are the most important risk factors for the development of chronic obstructive pulmonary disease (COPD) in developing countries (Mannino and Buist, 2007) [30]. COPD was responsible for 2% of the total global burden of diseases (Mathers and Loncar, 2006) [32].

Developing countries have been the focus for several investigations of health outcomes in household-generated biomass smoke exposures, primarily from the use of solid fuels for cooking. It has been estimated that one-half of the world's households continue to cook with solid fuels, approximately 95,6 of which consists of wood fuel or burning of agricultural residues (Smith *et al*., 2004). Incomplete combustion and poor ventilation in biomass burning devices used for cooking or heating can result in extremely high PM exposures in these households (Naeher *et al*., 2007; Smith *et al*, 2000) [34].

The burning of solid biomass fuels in an open fire or traditional cook stove results in release of high concentrations of toxic pollutants in the kitchen. In various developing countries wood stove emission is the main source of kitchen related indoor air pollution (Huboyo *et al*., 2014) [23]. About one third of households that cook inside the house do not have a separate kitchen room for cooking. In urban and rural areas, 9 in 10 households that use solid fuels for cooking in an open fire lack chimneys to divert smoke particles (IIPS and Macro International, 2007). The

chimney plays an active role in the performance of a stove by influencing the overall air to fuel ratio and subsequently the production of carbon monoxide (Prapas *et al*., 2014) [37].

Shilpa and Lokesh (2015) [40] studied the indoor pollutants emitted from different household fuels. The study was conducted for 2 hours before, during and after cooking time. The results have shown that the maximum concentration of NO2 and SO2 were recorded during cooking with coal while minimum was recorded for LPG. Similarly, CO (30ppm) concentrations were high during cooking period when coal was used. It was recorded that in biomass households the SPM (1438.5 µg/m^3) and RSPM (1484.89 µg/m^3) were high.

Households (kitchen) air pollution due to biomass combustion

Jiang and Bell (2008) [27] compared particulate matter from biomass-burning rural and non-biomass burning urban households in North-Eastern China and observed that in rural kitchens, PM10 levels were three times higher than those in urban kitchens during cooking and also that PM10 was 6.1 times higher during cooking periods than during non-cooking periods for rural kitchens. Their findings indicated that biomass burning for cooking contributed substantially to indoor particulate and that this exposure was particularly elevated for cooks.

Fuelwood has provided humans with cooking, heating and related energy needs for thousands of years and remains an important source of energy throughout the world (FAO, 2008). It has been estimated that more than half world's households cook their food on the unprocessed solid fuels that typically release at least 50 times more noxious pollutants than liquid petroleum gas (Smith, 2000).

The World Health Organization (WHO, 2009) reported that indoor air pollution as the greatest environmental health risk, mainly in the developing countries. This risk factor is the second largest environmental contributor to ill health, behind the combination of unsafe water with poor sanitation. Bruce *et al*. (2006) [10] concluded that biomass fuels are the second most significant environmental source of disease after contaminated waterborne diseases. Comparative Risk Assessment report 2004 of WHO attributes 3.3% and 2.8% of total deaths world over and in middle income countries respectively, to indoor smoke from solid fuels, which is one of the ten leading risk causes of death. Globally 4.3 million people die every year from the exposure to household air pollution (WHO, 2014; Smith *et al*., 2014). More than 1.45 million people, mostly women and children under five years old, die prematurely each year from household air pollution due to inefficient biomass combustion (WHO, 2008).

About 160 million Indian households now cooking with inefficient and polluting biomass and coal cookstoves and about 570,000 premature deaths in poor women and children, and over 4% of India's estimated greenhouse emissions could be avoided if cleaner and energy-efficient biomass used for cooking. In addition, about one-third of India's black carbon emissions can be reduced along with a range of other health- and climate-active pollutants that affect regional air quality and climate (Venkataraman *et al*., 2010) [46].

Martin *et al*., (2011) [31] reported that the emission of greenhouse gases from burning of various fossil fuels is mainly responsible for global warming which lead to climate change. Indoor air pollution is responsible for several health, environmental, and social issues that disproportionately and adversely affect women and young children around the globe.

Grieshop *et al*., (2011) [21] analyze and compare the impacts of household cooking options on health and climate. They found that the indoor air pollution is heavily impacted by combustion performance and ventilation; climate impacts are influenced by combustion performance and fuel properties, including biomass renewability. Health benefits involve reducing emissions and exposure stoves with chimneys and improved but unvented stoves can provide roughly an order of magnitude reduction in exposure relative to traditional options.

Traditional cooking stoves contributes to numerous health problems, releases climate-warming greenhouse gases and black carbon emissions, and makes worse local air quality and other environmental problems. In particular, unsustainable harvesting of fuelwood for cooking can lead to local forest degradation and accelerate deforestation, especially in densely-populated areas (Brooks *et al*., 2016) [9].

The concentration of indoor air pollutants varies among the different location of household. The level of CO, CO2, NO2 and SO2 was very high in kitchen as compared to living area. Similarly the concentration of PM10 and PM2.5 was more than that found in living area (Aakanksha, 2014) [1].

Half of the world's population and 90% of developing countries such as India still rely on unprocessed biomass which is responsible for death of 3 to 4 million peoples due to its combustion which are used by the rural and poor people of urban areas of the country. Unprocessed biomass releases 50 times more noxious pollutants like particulate matter, carbon monoxide, nitrogen dioxide, sulphur dioxide, formaldehyde and carcinogens such as benzo (a) pyrene and benzene (WHO, 2012).

Biomass is a renewable energy source that is routinely used for cooking in the developing world, especially in rural areas (Abeliotis and Pakula, 2013) [2]. In 2004, about 2.5 billion people in developing countries, especially in rural areas, relied on biomass, such as fuelwood, charcoal, agricultural waste and animal dung, as their primary fuel for cooking. Indoor air pollution caused by burning traditional fuels such as dung, wood and crop residues causes' considerable damage to the health of particularly women and children. Women and their small children are at increased risk due to the amount of time spent close to the stove in the kitchen.

Households (kitchen) air pollution effects on human health

Indoor air pollution (IAP) from poor quality household fuels in open fires or poorly designed stoves in developing countries has been linked to acute respiratory infection (ARI), chronic obstructive pulmonary disease (COPD), and lung cancer (Smith *et al*., 2000). Acute respiratory infections, primarily pneumonia, are the leading causes of morbidity and mortality in very young children in Bangladesh accounting for approximately 25% of all deaths in children under five and 40% of deaths in infants (Baqui *et al*., 1998) [6].

A pilot study conducted by Edelstein *et al*., (2008) [16] in Gondar region of Ethiopia to assess the awareness among the women about health effects showed that most of them were not aware about health hazards related to cooking smoke. Also it was reported that, 80% of rural women used biomass fuels with no ventilation facilities.

Indoor air pollution emitted from traditional fuels and cooking stoves has potentially large health threat in rural regions in Orissa. They found very high incidence of respiratory illness in people mostly among women and children (Duflo *et al*., 2008) [15]

Fullerton *et al*. (2008) [19] while carrying out studies on indoor air pollution from biomass fuel found that, one-third of the world's population burnt organic materials such as wood, dung or charcoal (biomass fuel) for cooking, heating and lighting. As per them, this form of energy usage was associated with high levels of indoor air pollution and thus, an increase in the incidence of respiratory infections, including pneumonia, tuberculosis and 67 chronic obstructive pulmonary disease, low birth-weight, cataracts, cardio vascular events and all-cause mortality both in adults and children.

Kinsey *et al*. (2009) [28] found that a long-time exposure to wood smoke has been associated with the dwarfing of children, wheezing in children, and cardiovascular and respiratory illnesses. Colbeck *et al*. (2008) [14] studied the indoor air quality at rural and urban sites in Pakistan and observed the PM10 concentrations of up to 8,555 µg per m 3 inside kitchens where bio fuels were burnt.

Pope *et al*. (2010) [36] established the relation between indoor air pollution (IAP) from solid fuel with low birth weight and still birth in developing countries. They found that IAP was associated with increased risk of percentage low birth weight (odds ratio=1.38, 95% confidence interval: 1.25, 1.52) and stillbirth (odds ratio=1.51, 95% confidence interval: 1.23, 1.85) and reduced mean birth weight (-95.6 g, 95% confidence interval: -68.5, - 124.7).

A short term effect of carbon monoxide causes headache, dizziness and nausea. Polyaromatic hydrocarbon benzopyrene, a carcinogenic substance is known to cause lung and mouth cancer, nasopharynx and larynx. Formaldehyde causes irritation of nasopharynx and airways while nitrogen dioxide and sulphur dioxide increases bronchial reactivity leading to wheezing, repeated respiratory tract infections and exacerbations of asthma. Biomass smoke particles cause oxidative changes in the eye lens leading to cataract in some individuals (Fernandes and Mesquita, 2014) [18]. 45 Symptoms like eye irritation, headache, and diminution of vision were found to be significantly higher in biomass users (Sukhsohale *et al*., 2013) [45].

Arora *et al*., (2014) [4] reported that the effect of chronic exposure to solid biomass fuel smoke on pulmonary function of women in rural areas of Haryana. Sixty women were selected for this study. Among these, 30 (Biomass users) women were from rural areas and 30 from urban areas (LPG users). The results showed that, the lung function parameters such as Forced vital capacity, Forced expiratory volume in first second, Forced expiratory flow rate, Maximum voluntary ventilation and Peak expiratory flow rate were significantly lowered in biomass users than LPG users. This could be due to the chronic significant exposure to biomass smoke. Also, inadequate ventilation and type of cook stove (without chimney) have contributed to irregular pulmonary function and COPD.

Exposure to biomass fuel is an important risk factor of lung cancer among women in addition to tobacco smoke exposure. Among non-smokers, of all the 48 cooking fuels the risk of development of lung cancer was highest for biomass fuel exposure (Bahera and Balamugesha, 2014). The higher mean biomass fuel smoke exposure index (52.15 hour/years) could be attribute to reduced lung function in rural women (Bihari *et al*., 2013) [8].

Inefficient fuel combustion in traditional stoves release gaseous products with a higher global warming potential than carbon dioxide, such as carbon monoxide (Ramanathan and Carmichael, 2008) [38]. Traditional stoves are still the most prevalent way of cooking in the developing countries regardless of their inefficiency and risks associated to human health and the environment (Arthur *et al.*, 2010) [5].

Pant *et al*. (2016) [35] found that the air pollution in homes of urban and rural areas due to use of biomass which have higher concentration of CO, CO2, dust particles and VOCs in urban kitchens as compared to rural kitchen and the symptoms of respiratory disease was more prone among the children.

Preventive measures to reduce household air pollution and its effects

One of the ways to overcome household air pollution problem is to energy transition or makes use of improved cook stove. Improved biomass cook stoves have been identified as an option to reduce negative impacts of cooking with traditional open fires studied by Mercado *et al*., 2011. [33]

A study by MacCarty *et al*., (2010) [29], investigated the performance of 50 different types of stoves. The level of carbon monoxide and particulate matter emitted from these stoves were recorded. The results showed 33% of fuel use and 75% of CO, 46% of particulate matter emission reduction by Rocket type stoves.

Clark *et al*., (2012) [13] found that there was significant reduction in systolic blood pressure only in women of over 40 years of age after installation of vented stove. Similarly, a significant risk reduction was observed in women after installation of a chimney (Chapman *et al*., 2005) [12]. Upon implementation of ONIL stove in rural homes of Guatemalan community, there was reduction in clinic visits by people for acute upper and lower respiratory (26%) and for acute lower respiratory illness (45%) studied by Harris *et al*., 2011. [22]

Panwar *et al*. (2009) reported that an improved biomass cookstove can save about 161kg of CO_2 annually. Improved cookstoves was found eco-friendly in nature and suitable for cooking requirement of hilly area.

Alam and Chowdhury (2010) [3] presented an improved earthen cook stove with two cooking stations and a chimney to reduce the fuel consumption rate. They evaluated the economic achievements of the improved cook stove. Frapolli *et al*. (2010) [20] reported that the adequately designed and disseminated improved cook stoves is a viable option for improving health and economic conditions of local people as well as local and global environmental conditions. They also reported that benefits from these cook stoves outweigh their costs by 7 fold and extremely attractive from social, economic and environmental perspectives. Improved cook stoves (ICSs) were compared to local traditional cook stoves (TCSs). The results of the WBTs were mixed. Although the improved stoves generally showed some improvement in efficiency for the low-power simmering phases, the stoves were less efficient than traditional stoves in high-power water-boiling phases. Three ICS models and one traditional stove were tested and compared by Islam *et al*., 2014. [25]

The Global Alliance for Clean cook stoves reports that only a fraction (0.25%) of Indian households (>1 million) use improved cook stoves (GIZ, 2014). WHO guidelines on indoor air quality standards recommend a complete transition to the use of gaseous fuels (LPG and biogas) or electricity based cooking to eradicate health impacts from pollution arising out of cooking (WHO, 2014).

Conclusion

Thus, it concluded that the combustion of biomass fuels under traditional biomass cook stoves causes indoor air pollution, health hazards and environmental problems. The literature indicates ambient IAP levels and personal exposure levels from cooking with traditional fuels are dramatically high. The reduction of air pollution within the household has the potential to have a direct effect on respiratory and even general health, if household tend be in better health due to the stoves, they can save much in medical expenditures, which tends to be a large portion of expenditures among the very poor and household members are in better health, there is a potential for the household to be more productive, with household adults missing fewer days of work and children missing fewer days of school. Using improved cooking stoves may be a way to reduce exposure to indoor air pollution, improve health, and decrease greenhouse gas emissions.

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