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32	Abstract	**Background and purpose:** In Pakistan, almost 70% of the population lives in rural areas. Ninety-four percent of households in rural areas and 58% in urban areas depend on biomass fuels (wood, dung, and agricultural waste). These solid fuels have poor combustion efficiency. Due to incomplete combustion of the biomass fuels, the resulting smoke contains a range of health-deteriorating	

substances that, at varying concentrations, can pose a serious threat to human health. Indoor air pollution accounts for 28,000 deaths a year and 40 million cases of acute respiratory illness. It places a significant economic burden on Pakistan with an annual cost of 1% of GDP. Despite the mounting evidence of an association between indoor air pollution and ill health, policy makers have paid little attention to it. This review analyzes the existing information on levels of indoor air pollution in Pakistan and suggests suitable intervention methods.

Methods: This review is focused on studies of indoor air pollution, due to biomass fuels, in Pakistan published in both scientific journals and by the Government and international organizations. In addition, the importance of environmental tobacco smoke as an indoor pollutant is highlighted.

Results: Unlike many other developing countries, there are no long-term studies on the levels of indoor air pollution. The limited studies that have been undertaken indicate that indoor air pollution should be a public health concern. High levels of particulate matter and carbon monoxide found have been reported, and generally, women and children are subject to the maximum exposure. There have been a few interventions, with improved stoves, in some areas since 1990. However, the effectiveness of these interventions has not been fully evaluated.

Conclusion: Indoor air pollution has a significant impact on the health of the population in Pakistan. The use of biomass fuel as an energy source is the biggest contributor to poor indoor air quality followed by smoking. In order to arrest the increasing levels of indoor pollution, there is a dire need to recognize it as a major health hazard and formulate a national policy to combat it. An integrated effort, with involvement of all stakeholders, could yield promising results. A countrywide public awareness campaign, on the association of indoor air pollution with ill health, followed by practical intervention would be an appropriate approach. Due to the current socioeconomic conditions in the country, development and adoption of improved cooking stoves for the population at large would be the most suitable choice. However, the potential of biogas as a fuel should be explored further, and modern fuels (natural gas and LPG) need to be accessible and economical. Smoking in closed public spaces should be banned, and knowledge of the effect of smoking on indoor air quality needs to be quantified.

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REVIEW ARTICLE

The state of indoor air quality in Pakistan—a review

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Abstract

Background and purpose In Pakistan, almost 70% of the population lives in rural areas. Ninety-four percent of households in rural areas and 58% in urban areas depend on biomass fuels (wood, dung, and agricultural waste). These solid fuels have poor combustion efficiency. Due to incomplete combustion of the biomass fuels, the resulting smoke contains a range of health-deteriorating substances that, at varying concentrations, can pose a serious threat to human health. Indoor air pollution accounts for 28,000 deaths a year and 40 million cases of acute respiratory illness. It places a significant economic burden on Pakistan with an annual cost of 1% of GDP. Despite the mounting evidence of an association between indoor air pollution and ill health, policy makers have paid little attention to it. This review analyzes the existing information on levels of indoor air pollution in Pakistan and suggests suitable intervention methods.

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Keywords Indoor air pollution · Biomass fuel · ETS · Pakistan

1 Introduction

Population exposure to various air pollutants is likely to be higher in the indoor micro-environment than outdoors due

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to the amount of time people spend indoors. Consequently, indoor air quality has drawn considerable attention in recent years. While indoors, people can be exposed to pollution from indoor sources as well as from outdoor sources that penetrate into the indoor environment. Worldwide, the major sources of indoor air pollution are combustion of solid fuels, tobacco smoking, outdoor air pollutants, emissions from construction materials and furnishings, and improper maintenance of ventilation and air conditioning systems (WHO 2006). Globally, there are noticeable differences in types and strengths of these sources, and they are closely linked to socioeconomic developments. In the developed world, the types, sources, concentrations of various indoor air pollutants, and their exposure profiles are significantly different from the developing world.

In developing countries, population explosion along with widespread industrialization coupled with urbanization has resulted in dense urban centers with poor air quality. In addition to the poor ambient air quality, people in developing countries can be exposed to high concentrations of indoor air pollution due to the use of biomass fuels as an energy resource. Worldwide, more than three billion people, largely in developing countries, rely on biomass fuels (wood, dung, and crop residues) for domestic energy needs (WHO 2007a). These solid fuels have traditionally been burnt with poor combustion efficiency under poorly ventilated conditions in devices such as earthen or metal stoves. As a result, levels of indoor air pollution are higher than those outdoors. Due to incomplete combustion, the resulting smoke contains a range of health-deteriorating substances that, at varying concentrations, can pose a serious threat to human health. The pollutants emitted include carbon monoxide, nitrogen dioxide, particulate matter, transition metals, fluorine, polycyclic aromatic hydrocarbons, volatile organic compounds such as benzene and formaldehyde, and free radicals (Fullerton et al. 2009; Kang et al. 2009; Zhang and Smith 2007; Naeher et al. 2007; Sinha et al. 2006; Mudway et al. 2005; HEI 2004; Tsai et al. 2003; Zhang et al. 1999; Cooper 1980). Wood smoke has also been reported to be probably carcinogenic (Straif et al. 2006; Hosgood et al. 2007).

Women and their small children are at increased risk due to the amount of time spent close to the stove in the kitchen. Indoor air pollution is responsible for more than 1.6 million annual deaths and 2.7% of global burden of diseases (WHO 2006). Indoor air pollution, from solid fuel use, is the tenth largest threat to public health (WHO 2007b). Hence, exposure to indoor air pollution from the combustion of biofuels is a significant public health hazard predominately affecting the poor in both rural and urban communities in developing countries. There is strong evidence that smoke from biofuels can cause acute lower respiratory infection in childhood (Fullerton et al. 2008; WHO 2006; Smith et al. 2000, 2004; Ezzati and Kammen 2001). Table 1 represents the health effects and strength of evidence due to the use of biomass fuels in developing countries.

Furthermore, a recent report on the national burden of diseases from indoor air pollution by the World Health Organization (2007a) confirms the linkage between indoor air pollution due to solid fuels and different diseases, including acute and chronic respiratory diseases, tuberculosis, asthma, and cardiovascular disease and prenatal health outcomes.

Many papers have been published on indoor air quality in developing countries: Malawi (Fullerton et al. 2009), Mexico (Zuk et al. 2007), Philippines (Saksena et al. 2007), China (Fischer and Koshland 2007; Mestl et al. 2007), Zimbabwe (Rumchev et al. 2007), Bangladesh (Dasgupta et al. 2006), India (Balakrishnan et al. 2002, 2004), Costa Rica (Park and Lee 2003), Bolivia (Albalak et al. 1999), and Kenya (Boleij et al. 1989). A number of studies on reducing indoor air pollution have been published (WHO 2008; Smith et al. 2006; Practical Action 2004). The interventions fall broadly into three categories: producing less smoke; removing smoke from the indoor environment; and by reducing exposure to smoke.

It is evident that there is very little published literature available regarding indoor air pollution in Pakistan. As Pakistan is a predominantly rural society where biomass fuel is the major source for cooking and heating, there is an

Table 1 Health effects of use of solid household fuels in developing countries

Disease	Population affected	Relative risk (95% confidence interval)	Strength of evidence
Chronic obstructive pulmonary disease	Females >15 years	3.2 (2.3, 4.8)	Strong
	Males >15 years	1.8 (1.0, 3.2)	Intermediate
Acute lower respiratory infections	Children <5 years	2.3 (1.9, 2.7)	Strong
Lung cancer (coal only)	Women >15 years	1.9 (1.1, 3.5)	Strong
	Men >15 years	1.5 (1.0, 2.5)	Intermediate
Blindness (cataracts)	Females >15 years	1.3–1.6	Intermediate
Tuberculosis	Females >15 years	1.5–3.0	Intermediate

Source (Smith et al. 2004)

urgent need to review and synthesize the information on the current levels of indoor air pollutants and interventions to improve indoor air quality within the country.

This review is predominately focused on the studies of indoor air pollution due to biomass fuels in Pakistan published in the scientific literature. The various efforts to improve indoor air quality are presented and recommendations put forward for future interventions to combat indoor air pollution.

2 Indoor air pollution and Pakistan

Pakistan is a mainly rural society with almost 70% of the population living in rural areas, and a vast proportion of these rely on biomass fuel for their energy needs. The use of biomass fuel in traditional three stone stoves (made of clay and husk) produces enormous quantities of smoke. The average household size is estimated at 6.8 persons. As 38% of households consist of a single room with a kitchen; these households have a greater concentration of indoor air pollution which leads to high exposure. The Pakistan Household Energy Strategy Study revealed that biomass fuels account for 86% of total household energy consumption in Pakistan (Archar 1993) (Fig. 1). In rural areas, 94% of households depend on biomass fuel, and in urban areas, the figure is 58%. The fuel is used for cooking (82.1%), water heating (9.8%), and domestic heating (7.3%) (Archar 1993).

The health indicators of Pakistan are disappointing. Over the last 60 years, although there have been some improvements in the health status of the population, key health indicators still lag behind other regional countries. Maternal mortality rate has declined from 800 per 100,000 live births in 1978 to the presently reported figure of 350, and the infant mortality rate has declined from the 142 per 1,000 live births in 1970 to 74.6 in 2006. Diarrheal diseases and acute respiratory infections (ARI) dominate the child mortality rate spectrum in Pakistan. Mortality due to infectious diseases such as diarrhea and vaccine-preventable diseases has reduced over the last decades. However, improvements have not occurred in other areas such as ARI (Nishtar 2007). A 2004 survey has shown that 34% and 28% children less than 5 years old had developed symptoms of ARI and diarrhea, respectively, in the preceding 2 weeks of the study (Multiple Indicators Cluster Surveys of Pakistan 2001–2004).

According to Pakistan Strategic Country Environmental Assessment by the World Bank (World Bank 2006), indoor air pollution accounts for 28,000 deaths per year and 40 million cases of acute respiratory illness. Indoor air pollution is a significant economic burden in Pakistan and annually costs 1% of GDP. Table 2 presents the estimated annual health impacts in terms of annual cases and disability adjusted life years (DALYs). Up to 1,376,000 DALYs are lost each year due to indoor air pollution of which 82% is from mortality and 18% from morbidity.

The World Health Organization (2007~~b~~) has assessed the burden of disease from indoor air pollution at the national level (Table 3). In 11 countries (Afghanistan, Angola, Bangladesh, Burkina Faso, China, the Democratic Republic of the Congo, Ethiopia, India, Nigeria, Pakistan, and the United Republic of Tanzania), indoor air pollution is to blame for a total of 1.2 million deaths a year. ~~Globally, reliance on solid fuels is one of the 10 most important threats to public health.~~ For Pakistan, the number of deaths due to pneumonia and other acute lower respiratory infections among children under 5 years of age was estimated to be 51,760, the number of deaths due to chronic obstructive pulmonary disease 18,980, the total number of deaths attributable to solid fuel use 70,700 and the percentage of national burden of disease attributable to solid fuel use 4.6%. Their estimate for DALYs attributable to solid fuel use was 2,057,400; nearly 50% higher than that of the World Bank.

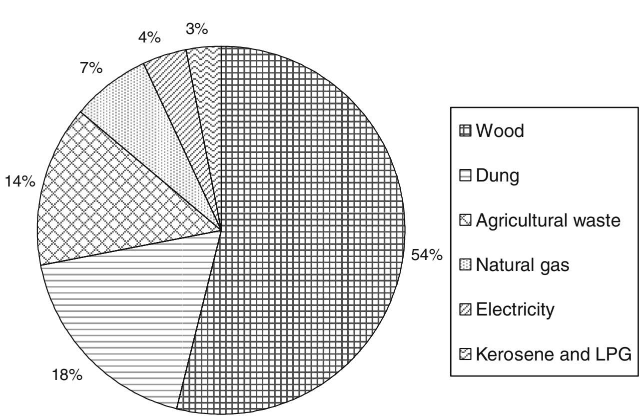

Fig. 1 Household energy use by fuel type in Pakistan (%). Data from Archar (1993)

3 Studies on indoor air pollution

Compared to other developing countries, few measurements have been published on indoor air quality in Pakistan with the first measurements only reported in 2001 (Jabeen et al. 2001). Dust samples from nine selected houses in Gugranwala were analyzed for heavy metals (Pb, Cd, Zn, Cu). The majority of the dust indoors originated outdoors with the Pb indoor/outdoor ratio varying from 0.35–0.97. In well-ventilated houses, this ratio was close to 1 while in houses with poor ventilation, it was much less. Similar trends were observed for all the metals.

Siddiqui et al. (2005a) reported that mothers using wood as fuel ~~give~~ birth to children with reduced weight compared to those who used natural gas. The mean daily levels of CO

Table 2 Estimated annual health impacts due to indoor air pollution in terms of annual cases and disability adjusted life years

	Estimated annual cases		Estimated annual DALYs		% of total DALYs
	Low	High	Low	High	
Acute respiratory illness					
Children (under 5)—increased mortality	21,933	31,060	745,718	1,056,029	77
Children (under 5)—increased morbidity	29,508,800	41,788,200	48,690	68,951	5
Females (age 30 and older)—increased morbidity	10,754,600	15,229,800	75,282	106,609	8
Chronic obstructive pulmonary disease					
Adult females—increased mortality	7,408	11,433	44,450	68,600	5
Adult females—increased morbidity	21,850	33,721	49,163	75,873	5

Data from (World Bank 2006)

for wood use and natural gas were 24 and 5 ppm while the levels of $PM_{2.5}$ were 12 and 0.25 mg/m^3, respectively. However, during cooking periods in the kitchens using biofuel, a sharp rise in concentration of CO (150 ppm) and $PM_{2.5}$ (300 mg/m^3) was seen. Siddiqui et al. (2005b) also compared self-reported eye and respiratory symptoms among the women using wood and natural gas. The results confirmed that wood users had a higher frequency of eye congestion, nasal congestion, throat-related symptoms, and cough than natural gas users. Furthermore, an interactive effect of age with wood use was reported as acute eye symptoms were found more common among those younger than 28 years old. Overall, this study reported a significant association of wood use with eye and respiratory symptoms.

A study by Akhtar et al. (2007) revealed a strong association between biomass smoke and chronic bronchitis in women in the rural area of Peshawar. This study was carried out with 1,426 female test patients using various types of biomass fuels and 1,131 female control subjects using liquefied petroleum gas as an energy source. These findings clearly reflect the risks of biomass fuel usage. Nonetheless, no measurements of air quality were made during the study, and only interviews were conducted with the participants.

Colbeck et al. (2008) reported the results of an investigation on indoor air quality at rural and urban areas of Pakistan. Measurements were made of particulate mass (PM_{10}, $PM_{2.5}$, and PM_1), number concentration and bioaerosols in different

Table 3 Burden of disease due to indoor and outdoor air pollution for various countries

	Population (000)	Indoor Air Pollution		Outdoor Air Pollution	
		Population using solid fuel (%)	Deaths per year	Annual PM_{10} (μg/m^3)	Deaths per year
Bangladesh	143,809	89	46,000	157	8,200
Cambodia	13,810	>95	1,600	51	200
China	1,302,307	80	380,700	80	275,600
India	1,049,550	82	407,100	84	120,600
Indonesia	217,131	72	15,300	114	28,800
Malaysia	23,965	<5	<100	28	500
Myanmar	48,852	>95	14,700	75	3,900
Nepal	24,609	81	7,500	161	700
Pakistan	149,911	81	70,700	165	28,700
Philippines	78,580	45	6,900	34	3,900
Republic of Korea	47,430	<5	–	43	6,800
Singapore	4,183	<5	–	48	1,000
Sri Lanka	18,910	67	3,100	93	1,000
Thailand	62,193	72	4,600	77	2,800
Vietnam	80,278	70	10,600	66	6,300
Asia			971,200		517,700
World	6,213,869	52	1,497,000	61	865,000

Source (WHO 2007a~~, b~~)

micro-environments. PM_{10} concentrations up to 8,555 μg/m^3 were observed inside kitchens where biofuels were burnt. Cleaning and smoking was also identified as a major source of indoor particulate pollution, and concentrations more than 2,000 μg/m^3 were recorded in the living room during these activities. An extension of above work was carried out, and number concentrations were reported from rural and urban households (Colbeck and Nasir 2008a). The values of the number concentration in living rooms at Lahore were in the range 14,000–181,000 cm^{-3}. While at rural sites, a maximum concentration of 156,000 cm^3 was obtained. On the other hand, the highest number ~~of~~ concentration~~s~~ was recorded from the urban kitchens using natural gas (246,000 cm^{-3}) as compared to rural kitchen using biomass fuel (220,000 cm^{-3}) and natural gas (226,000 cm^{-3}).

In another study on bioaerosols, Colbeck and Nasir (2008b) examined 42 houses in urban and rural areas of Pakistan. The air samples were taken with an Anderson six-stage viable particle sampler, loaded with Malt Extract Agar, MacConkey Agar, and Trypticase Soy Agar. In Lahore, the highest total bacteria (13,900 CFU/m^3) and fungal (5,300 CFU/m^3) concentrations were found among houses in slums. However, the outdoor levels were generally higher than those indoors. The highest outdoor concentration of total bacteria and fungi was 20,700 and 3,300 CFU/m^3, respectively. On the other hand, in rural sites, the maximum concentration of total bacteria and fungi was 29,200 and 32,800 CFU/m^3. The indoor levels of bioaerosols were higher than those outdoors in all of the samples, probably due to indoor cattle sheds and excessive use of wood as construction materials. Similarly, the upper concentration of Gram-negative bacteria was higher in rural houses than in urban areas. Most of the total bacterial aerosols were present in the size range 2.1 to 7 μm while the highest concentration of Gram-negative bacteria occurred between 0.65 and 1.1 μm. The maximum percentage of fungal aerosol was present between 1.1 and 3.3 μm.

Khudadad and Shah (2008) conducted a baseline study in 63 households in the Ishkoman Valley, northern Pakistan. The mean indoor concentration of $PM_{2.5}$ was 7,380 μg/m^3 with a maximum of up to 206,000 μg/m^3 during cooking hours. Outdoors, the mean concentration of $PM_{2.5}$ was 80 μg/m^3 with a maximum of 258 μg/m^3.

The levels of carbon monoxide and $PM_{2.5}$ in kitchens using wood or natural gas as a cooking fuel were reported by Siddiqui et al. (2009). The 8-h average CO concentration for wood users was 29.4±16.2 ppm while natural gas produced only 7.5±4.4 ppm. The mean $PM_{2.5}$ concentration for wood was 2.74±2.1 mg/m^3 compared to 0.38±0.39 mg/m^3 for natural gas kitchens.

Recently, Colbeck et al. (2009) reported the results of a study carried out on indoor/outdoor particulate pollution in rural and urban residential environments. In the kitchens of rural areas using biomass fuel, the 24-h average indoor concentration of PM_{10}, $PM_{2.5}$, and PM_1 was 1,581±2,003, 1,169±1,489, and 913±992 μg/m^3, respectively. In rural living rooms, for the same time period and particle size, the concentrations were 953±641, 603±421, and 548±400 μg/m^3, respectively. On the other hand, in the urban living room, the 24-h average indoor mass concentrations for the same size fractions were 533±641, 402±641, and 362±641 μg/m^3, respectively. Cooking, cleaning, and smoking were identified as the principal contributors to high indoor levels of particulate matter.

The levels of particulate matter and CO reported in the above studies are many times higher than those in the developed world. Indoor levels of $PM_{2.5}$, measured within the framework of the European EXPOLIS study, in Athens (Greece), Basel (Switzerland), Helsinki (Finland), and Prague (Czech Republic) showed that mean indoor concentrations in these European cities were 35.6±29.4, 21±16.7, 9.5±6.1, and 34.4±28.7 μg/m^3, respectively (Götschi et al. 2002). In UK, Wigzell et al. (2000) found that 48-h mean concentration of $PM_{2.5}$ in the kitchens ranged from 5 to 77 μg/m^3 with a mean of 18 μg/m^3. Recently, Mohammadyan and Ashmore (2005) reported that the geometric mean indoor concentration of $PM_{2.5}$ was 19 μg/m^3 with higher values in winter (46 μg/m^3) than in summer (13.4 μg/m^3). During the RIOPA study in three different areas of USA (Elizabeth NJ, Houston TX, and Los Angeles County CA) Meng et al. (2005) reported that median indoor $PM_{2.5}$ was 14.4 μg/m^3.

The available information on the current situation of indoor air pollution, though sparse, clearly reflects the severity of indoor air pollution in Pakistan. In general, the scope of human health has been neglected despite the National Environmental Policy (2005–2015) having as one of its goals the establishment and enforcements of standards for ambient and indoor air quality (National Environment Policy of Pakistan 2005).

4 Interventions to control indoor air pollution

Initial efforts to introduce more fuel efficient stoves in some areas of the country commenced over 20 years ago. Before 1988, only 2,500 improved cook stoves were constructed in Pakistan. The Fuel Efficient Cooking Technologies project resulted in the production and dissemination of some 40,000 stoves in 1990 (Sarhandi 1997). A later program, on fuel-saving technologies, provided incentives to NGOs and community-based organizations for its implementation (Anwer 2001). The benefits of using the improved stoves, in terms of reduced smoke levels, were reported by Saleem (1997) and Ahmad and Nazir (1997) from northern areas of Pakistan and Peshawar. Saleem (1997) reported the

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introduction of the improved stoves resulted in a fall respiratory and eye diseases. Moreover, these improved stoves reduced the workload of women and pressure on the natural forests due to savings in biomass fuel consumption. However, these stoves were not considered economical for poor families. Ahmad and Nazir (1997) concluded that the stoves were far better in terms of heating capacity, wood saving, cooking efficiency, and smoke reduction as compared to their traditional counterparts.

Most interventions have focused on northern areas of Pakistan due to the degradation of natural resources. Deforestation as a result of wood use for construction and fuel has resulted in land degradation and soil destabilization which, in turn, has led to diminished economic prospects for the local population. The Building and Construction Improvement Program (BACIP), established in 1997, has installed over 17,000 energy-efficient and living condition improvement products in various households, benefiting nearly 70,000 people across 125 villages. These include fuel-efficient "smoke-free" cooking stoves with chimneys, as well as wall and floor insulation, and roof hatch windows to reduce dust particles and improve indoor heating (Sedky and Hussain 2001).

Of special note is the use, by BACIP, of women from local villages to disseminate its products. Demonstration models are used in a few homes so that the villagers can directly witness the benefits and learn about appropriate use. By utilizing women residents, to provide input into the design and decision-making processes, it gives them a greater voice and enhanced status in the community. Crucial to the success of the program is the use of simple technologies and local materials. Sustainability is enhanced due to the products' low cost (around \$30 a stove) and local production. It is estimated that this program has reduced in-house smoke and other air pollutants by over 80%. Approximately 300,000 trees have been saved with a reduction in average household fuel wood expenditure of 50%. A 50% decrease in incidences of acute respiratory infection, pneumonia, and other illnesses has been predicted.

In 2003, a BACIP, with support from local government, was commenced in Sindh province in South Pakistan. A similar participatory research and implementation process to that in the North has allowed for easy replication, and new products have been designed that match cultural and climatic requirements.

In order to estimate the acceptability, social, and health impacts of improved stoves a cross sectional study was conducted by Khushk et al. (2005) between households using smoke-free stoves and traditional stoves during April to May 2002. Smoke-free stoves were regarded as having a beneficial impact on health by most of the women. The results of multivariate analysis showed that symptoms of dry cough, sneezing, and tears while cooking were less common in women using the smoke-free stoves than those using traditional stoves. The mean concentration of CO in smoke-free kitchens was 15.4 ± 3.4 compared to 28.5 ± 5.7 ppm with traditional stoves.

Apart from improved cooking stoves, the Government of Pakistan started a comprehensive biogas program in 1974 and had commissioned 4,550 plants by 1990. The program was developed in three phases. Initially, the government installed 100 units, and in the second phase, the cost was shared between the Government and beneficiaries. In third phase, only beneficiaries bore the cost. Nevertheless, due to withdrawal of Government financial support the program did not progress (Anwer 2001). Although these pilot projects showed promising results, they were at a small scale and lacked the coordination among all the stakeholders.

The WHO Department of Child and Adolescent Health and Development review of the household energy usage concluded that indoor air pollution had not been recognized as a hazard and that very little intervention was being carried out in Pakistan (WHO 2005). Based on this review, a seminar was held to increase awareness of indoor air pollution due to biomass fuels and its effect on children's health (WHO 2006). There were presentations on a variety of issues including possible local initiatives such as fuel efficient stoves and the promotion of liquefied petroleum gas.

Details of intervention studies in other countries are widely available (e.g., WHO 2008; Granderson et al. 2009; Practical Action 2004; McCracken et al. 2007). While it is not feasible to develop a harmonized protocol to meet the needs of every project and location, much can be learned from evaluating the reasons for the success or failure of the various interventions (WHO 2008). It is clear that a participatory approach works well with communities. This involves household discussions about the health risks of indoor air pollution, and working with them to find solutions which not only reduce smoke but also simultaneously enhance the comfort and quality of their lives.

What is lacking in Pakistan is a baseline assessment of pollution and exposure, fuel use, and house structure. Although cook stove emissions contain a wide range of pollutants, it is generally agreed that particulate matter and carbon monoxide should be monitored as they are the pollutants considered most damaging to health (WHO 2008). Dissemination of the results to the local community can help towards attitudinal change and positive behavioral changes. However, changing cooking behaviors are unlikely to bring about reductions without other interventions; they are important supporting measures. Where cleaner fuels such as gas are introduced, NO_2 is likely to become more important as a pollutant in kitchens. Little research has been directed towards kitchen design and behavior change although these could offer significant improvements. For example, having the stove at waist height would reduce the need to lean over the fire and hence reduce direct exposure to smoke.

5 Environmental tobacco smoke

Alongside the use of biomass fuels, environmental tobacco smoke (ETS) is another significant indoor air pollutant and major public health problem in Pakistan. Smoking in confined spaces (house, office, transport) is a common practice. There is significant evidence that ETS is an important source of fine particulate and responsible for an increase in indoor fine particulate in the range 10–45 μg/m^3 (Nazaroff and Klepeis 2003). There is a scarcity on studies on the levels of indoor pollution due to ETS in Pakistan. Ahmad et al. (2005) reported the results of a nationwide cross-sectional household survey to estimate the prevalence of, and identify factors associated with, smoking in Pakistan. Overall, the prevalence of smoking was 15.2% with 28.6% among men and 3.4% among women. The highest prevalence was reported in men aged 40–49 years (40.9%). One out of every two to three middle-aged men in Pakistan smoke cigarettes. Other studies have considered the prevalence of smoking in different social groups, occupations, and locations in Pakistan. For comparison, in India, the prevalence of smoking was 15.6% with 28.5% among men and 2.1% among women (Jindal et al. 2006); in Bangladesh, the corresponding figures are 55% and 17%, respectively (WHO 2003).

Various studies have documented the prevalence, knowledge, and practices regarding smoking among adults (Merchant et al. 1998; Khuwaja and Kadir 2004; Nisar et al. 2005, 2007; Ali et al. 2006, 2008; Ganatra et al. 2007; Maher and Devji 2002; Alam et al. 2008); house physicians and doctors (Piryani and Rizvi 2004); school, college, and university students (Rozi et al. 2005, 2007; Jawaid et al. 2008); medical students (Khan et al. 2005; Mubeen et al. 2008); and in air-conditioned coaches (Mal et al. 2001). Most of the studies have revealed that smoking is a major problem especially in younger age groups. Illiteracy and lack of awareness about the health hazards has been shown to be important factors; nevertheless, studies on medical students revealed that the frequency of smoking among young doctors was higher than the overall prevalence of smoking in Pakistan (Piryani and Rizvi 2004). Although these studies were not aimed at the investigation of indoor air pollution due to ETS, they revealed the increasing prevalence of smoking in all segments of society. As smoking in indoor environments is very common, ETS makes a significant contribution to indoor air pollution in the country. Recently, a study by Colbeck et al. (2008) reported an hourly concentration of PM_1 more than 2,000 μg/m^3 during smoking in living rooms in Pakistan. In this case, the room was occupied by up to five smokers. For comparison in western houses, smoking has been reported to increase indoor $PM_{2.5}$ concentrations by 25 to 45 μg/m^3 (McCormack et al. 2008; Breysse et al. 2005; Wallace 1996; Wallace et al. 2003). The current situation calls for an urgent need for health promotion and anti-tobacco education in combating the epidemic of smoking in Pakistan. In 2002, Pakistan introduced the Prohibition of Smoking and Protection of Non Smokers Health Ordinance which instigated a ban on smoking in closed places, health facilities, educational facilities, and on public transportation. However, the legislation is not implemented, and in 2008, the Government issued guidelines for the creation of designated smoking areas.

6 Conclusions

Indoor air pollution has received little attention in Pakistan because of lack of awareness among the population and policy makers regarding the association of indoor air pollution and ill health. The available information depicts high levels of indoor air pollution due to the use of biomass fuels and indoor smoking. Women and children are the most exposed proportion of the population due to amount of time spent near the stove or as passive smokers in the indoor environment. Poor indoor air quality, due to biomass fuel usage, needs urgent interventions, and it should be locally acceptable and viable. In particular, it should be economical and consider the role of women in the rural energy system and factors responsible for fuel choice decisions. In the first instance, a public awareness campaign regarding the health effects of indoor air pollution should be instigated followed by suitable community-based interventions. Schools and basic health units, along with a general media campaign, can provide an avenue to spread the knowledge of indoor air pollution due to biomass fuel usage and indoor smoking across the country.

Due to the current socioeconomic conditions in the country, development and adoption of improved cooking stoves for the population at large would be the most suitable choice. Elsewhere, this type of intervention has already shown a reduction in risk factors and improvement in health. In a study on a randomized trial of improved wood burning stoves in Guatemala, Smith et al. (2006) reported a reduction in infant pneumonia upon switching from open fire stoves to improved stoves. Furthermore, a significant drop in women's blood pressure was also recorded (McCracken et al. 2005). In addition to improved stoves, there is potential for using biogas as a rural energy source. There is a need for an integrated approach and the financial support by the Government, and the involvement of various community-based organizations is vital for the success. The work carried out by various governmental organizations (The National Institute of Silicon Technology, Pakistan Council of Scientific and Industrial Research, Pakistan Council of Appropriate Technology) on renewable energy resources needs consideration and marketing. Moreover, access to modern cooking fuels (natural gas, LPG) should be enhanced. With reference to environmental tobacco smoke, strict legislation on smoking in confined public places should be implemented. General public awareness about role of indoor smoking in the deterioration of indoor air quality and hazardous health effects of smoking along with practical support to quit should be provided at basic health units in the country. There is a dire need to conduct studies, not only to establish the effects of interventions but also on the levels of various indoor air pollutants in both rural and urban areas. Addressing women and children's indoor health and comfort-related issues generates commercial, environmental, and socioeconomic benefits.

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Q1. References (Smith and Liu 1994; Smith and Mehta 2003) were not cited in text. Please provide citations.