Indoor Air Pollution (IAP) Traceable to Household Fuel Consumption and its Impact on Health

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ABSTRACT

Energy is an essential and obligatory prerequisite of life. Indoor air pollution is one of the biggest environmental problems in the world being specifically concentrated in resource limited settings. Inspite of the availability of cleaner fuel technologies, people in resource limited setting still depend on traditional fuel to meet their basic needs resulting even in premature deaths. In Nepal people in rural areas are the pre-dominant users of biomass fuel, there is limited research focusing on rural areas particularly; women as they spend most of their time in kitchen. Reports were extensively searched for literature using preset keywords in English language peer-reviewed journals databases PubMed and Google Scholar published between the years 2005 to 2020. Citation details were examined, titles and abstracts screened for eligibility and if relevant, full text was also reviewed in greater detail. Findings were then presented primarily under two bold themes: Household fuel consumption: existing theories and evidence; and health impact of indoor air pollution. Several health effects were reported of indoor air pollution including respiratory illnesses, cardiovascular diseases, cancer, endocrine system disruption and pregnancy complications. These exposures almost double the health risks predominantly among children and women of rural communities as they are directly involved in household activities causing air pollution. Based on our review of evidence, women and children of rural households were the major victims. Further, determinants of household fuel consumption and health effects should be considered while formulating policies in regard to promoting accessibility of clean fuels and reducing household air pollutants.

KEY WORDS

Health impacts, Household energy consumption, Indoor air pollution, Low and middle income countries, Nepal, Rural women.

INTRODUCTION

Energy is the utmost to meet almost all basic needs of life and also an obligatory prerequisite for good health.[1] One of the world's largest environmental problems; indoor air pollution defined as using biomass materials as the primary fuel source in the home particularly in the resource limited setting of the world. Lacking access to clean fuels for cooking leads to the exposure of such nature and is likely to be a leading population-attributable risk factor for Chronic Obstructive Pulmonary Diseases (COPD), particularly among women in resource-poor settings.[2] Around 3 billion people worldwide share their equity in many different forms as open fires or simple stoves fueled by kerosene, biomass (wood, animal dung and crop waste) and coal to meet their basic energy needs resulting nearly 4 million premature deaths of young children and adults annually from respiratory, cardiovascular diseases, and cancer.[3,4] Such inefficient cooking practices leads to the direct accelerated production of pollutants including soot particles along with other health hazardous emissions that are able to penetrate deep into the lungs ultimately posing

serious health adversities and often fatal as well. In poorly ventilated settings, exposure to indoor smoke induced fine particles can be as high as 100 times as compared to their acceptable limit.[3]

Lack of adequate ventilation limits the outdoor air and hinders overall air circulation increasing the level of pollutants concentrated inside soaring the level of exposure.[5] Conventionally people of Low and Middle Income countries (LMICs) are the main users of solid biomass fuels (wood, charcoal, crop residues, and animal dung etc) for cooking and heating. World Health Organization (WHO) estimates the number of people having access to clean energy and technologies is likely to be constant by 2030 unless a substantial change in the policy is achieved, most possibly hindering the achievement of the 2030 Agenda of Sustainable Development.[3]

Indoor air pollution is one of the leading risk factors for deaths globally; moreover in case of low-income households, it's the leading risk factor for premature deaths contributing a total of 6% deaths in low-income countries.[6] Combustion of solid fuel for cooking can generate concentrations of pollutants in kitchens 100-200 times higher than current ambient air standards.[7] Of the 4.3 million observed death from exposure to household air pollutants; stroke (34%), ischemic heart disease (26%), chronic obstructive pulmonary disease (22%), pneumonia (12%) and lung cancer (6%) were major health adversities. Women and young children spending the most time near the domestic hearth are particularly vulnerable. Inhalation of indoor smoke was found to double the risk of pneumonia and other acute infections of the lower respiratory tract among children below five years of age. In-addition, more than 50% of pneumonia deaths among children under 5 are linked to household air pollution.[8] Women using coal are found with double risk of lung cancer, and are three times more likely to suffer from COPD, such as chronic bronchitis or emphysema, than women who cook with alternative fuel such as electricity, gas or other cleaner fuels.[1]

In Nepal, more than 80 percent of the Nepalese population reside in rural areas and around 77% households rely on biomass fuel for cooking and heating purposes and its use will continue to dominate for some time in near future.[9] Approximately, 7,500 people (2.7%) in Nepal die annually due to different diseases caused by the indoor air pollution affecting women and children at most. The continuous efforts of Nepal in making all households free of indoor air pollution by 2022 through promotion of clean cooking technologies seems quite difficult with the majority of households still being highly dependent upon traditional biomass energy.[10]

Despite the magnitude of the problem regarding indoor air pollution in resource limited settings including Nepal, the health impact of this environmental exposure has been relatively neglected by researchers, donors and policy makers. Although various studies have been performed that quantify health effects of indoor air pollution in the country, the amount of data available is surprisingly low. Nepalese people living in remote areas predominantly use solid biomass fuel but we find very limited data and research regarding the relation between indoor air pollution and its impact on health of rural women. In this paper, we documented the evidence on household fuel consumption and indoor air pollution; its effects of exposure on human health. In particular, this review highlights the changing pattern of household energy consumption and its effects on health, especially of rural women.

METHODS

This review aims to document the evidence on household fuel consumption, its determinants and indoor air pollution and hence, the effects of indoor air pollution on human health; particularly in the women of rural settings. To address our study questions, we sought to identify all reports in peer-reviewed journals conducting an extensive search of literature using keywords "household fuel consumption", "determinants of household fuel consumption", "indoor air pollution", "health effects", "human health" and "Nepal". The English language databases PubMed and Google Scholar were used to search the literature. Research published between 2005 and 2020 were considered as literature sources of this review. Findings of this review presented were illustrated mainly under two themes: Household fuel consumption and indoor air pollution; and health effects of indoor air pollution. In terms of approach, detailed citations were examined, titles and abstracts screened for eligibility, if relevant full text was also reviewed in greater detail and findings applicable to this literature review presented. Altogether 58 journal articles, 5 reports, 7 webpages and 6 books were cited.

REVIEW OF EVIDENCE

Two major themes regarding indoor air pollution as mentioned below were identified using defined search strategies. Papers were considered to merit scrutiny of the full article after their full title and abstract had been considered.

Household Fuel Consumption: Existing Theories and Evidence

More than 2 billion households still rely on traditional fuels to meet their energy needs despite cleaner fuels being important drivers for social and economic development. As use of traditional fuel impose severe adversities towards human health and the environment as a whole, transition from traditional fuel to cleaner fuels is needed to overcome those adversities and to improve the living conditions of the poor. To achieve this, it is necessary to understand fuel consumption patterns at different household levels, its

transition on various levels and search for updated policies to support this transition process.[11]

Existing Theories

The two most common approaches explaining the household fuel consumption have been detailed below highlighting examples from different countries.

The energy ladder theory

In parallel to the fuel-wood crisis in the 1970s-1980s the concept of energy ladder emerged, which in case of developing countries, is commonly used to explain the household fuel choices.[11-13] The 'Energy Ladder' theory explains the tendency of a family to move gradually from their choice of traditional fuel to intermediate and ultimately to the adoption of modern fuel is parallel to the rise in their income level.[11,12] Household fuel consumption varies depending on the socio-economic status of that particular household.[12] This fact is further supported by the empirical studies conducted around the world which showcases the association between the household income level and choice of household fuel.[14-18]

The fuel stacking theory

Although households move up for adopting traditional to modern fuel with the improvement in their economic status as solely depicted by energy ladder theory, there still exist a large number of other factors determining the household choice for fuel.[12] Increasing numbers of studies on household fuel consumption showed that the fuel switching process is not linear and simple as it looks rather, it involves inter-linkage between various complex factors that pose direct influence in decision making regarding their fuel choice. With the improvement in household economy, households may adopt new fuel and technologies in combination with traditional ones but are less likely to completely replace traditional fuel with modern ones.[13] Observation of these patterns led to development of new concept of 'Fuel Stacking' or 'Multiple Fuel Model' which is more relevant to explain fuel consumption in household level.[12,13] Several factors such as accessibility, affordability and convenience of fuel, sense of energy security, household preferences and familiarity with cooking using traditional technologies, other household characteristics such as household size, education level, ethnicity and region of residence are established in influencing the decisions related to energy consumption and fuel choice.[19,20]

Empirical Evidence on Household Fuel Consumption

WHO estimated that still around 3 billion people worldwide rely on traditional fuel to meet their daily basic needs for cooking energy particularly concentrated in low and middle income countries across Asia, Africa and Latin America; regions lacking access to clean or modern energy. There are wide variations in the level of consumption and the types of fuels used by households with respect to the geographical regions they reside. Significant numbers of countries where more than 95% households depend on solid fuels for cooking are concentrated in sub-Saharan Africa. In the year 2011, the Organization for Economic Co-operation and Development (OECD) consumed the most (40%) of global residential kerosene consumption, followed by non-OECD Asia (31%), Middle East (18%), Africa (9%) and Latin America (3%).[21]

In European Union (EU), households represented more than one-third (26%) of final energy consumption in 2018 of which natural gas accounted for 32% of the EU final energy consumption in households, electricity for 25%, renewables for 20% and petroleum products for 12%. The main use of energy by households was for heating their homes (64% of final energy consumption in the residential sector), with renewable accounting for more than a quarter (27%) of EU households space heating consumption.[22]

A nationally representative Demographic and Health Survey data from seven countries across southern Africa reported two-third of the households relied on biomass to meet their cooking needs.[23] Similar findings of using biomass as a prime source of energy in cooking was also observed in cross-sectional studies conducted in Malawi and Kenya.[24,25]

A field study on residential energy consumption in selected countries of South Asia indicated nearly all the demand is covered by electricity (80%), with Liquid Petroleum Gas (LPG) used for cooking. In Southeast Asian cities gas delivery pipelines have not been laid, so there is no consumption of piped gas. In outlying farming villages electricity use is about half that in urban areas, with LPG and other fuels, such as biomass fuels, used. Biomass fuel is mainly firewood, but coal briquettes are also used for cooking.[26] In contrast, a study based on the household data collected from three countries in South Asia namely Bangladesh, India and Nepal showed that households are predominantly using fuel-wood as their main source of energy: 98% of households in Bangladesh, 90% in Nepal and 73% in India, followed by dung cake. One of the interesting findings of this study is that more than half (55%) of rural farming households in India used LPG and electricity, whereas it was 29% in Nepal and only 2% in Bangladesh.[27] Similar to these findings, evidence from Asia and the Pacific supports fossil fuels (coal, oil and natural gas) as primary sources of energy supply, accounting for 85.2 percent of primary source of energy supply in 2014.[28]

In Nepal, biomass fuel particularly firewood is the dominant form of fuel used for household cooking. Almost 8 of 10 households are dependent on solid fuels for cooking. This proportion may rise up to 90% in rural context however only 33% of the urban dwellers use solid fuels for cooking.[29] Other forms of household fuel such as LPG, biogas and electricity occupy a small proportion (16%) for cooking.[30] During a typical month, households were likely to use multiple sources of energy and energy switching, mixing or stacking were common depending on several factors such as availability and access to electricity, capacity to pay for

the energy source and other socio-economic or cultural factors.[31] Per-capita fuel consumption in winter is double as that of other measured seasons and was attributed to greater prevalence of use and fuel consumption by supplemental stoves, not the main cooking stove.[32] An empirical analysis of data from Annual Household Survey (AHS) reported the use of firewood dominated the total share of the household energy consumption. The reason for the dominating role of firewood being the imbalance of demand and supply of other, cleaner energy sources such as electricity and petroleum products, the purchasing parity of households, traditional agriculture as a major economic activity, and the ease of trading the abundant labor for obtaining firewood compared to cleaner sources of energy.[33] A modeling study conducted in 2018 to analyze the future residential cooking energy demand and its environmental and economic impacts from 2015 to 2035 using a Long-range Energy Alternative Planning System (LEAP) tool projected that traditional biomass would still dominate the sources for the household cooking energy. The demand of modern fuels such as LPG, kerosene and electricity is increasing, and this demand would increase significantly throughout the period with the growth of the economic sector, urbanization ratio and the living standards of people.[34] Similarly, a study conducted to identify the determinants of household's choice of energy for the purpose of cooking using data from the Nepal Living Standard Survey (NLSS) concluded a total of 69 per cent of the households relied on low efficient biomass fuel (fuel-wood and agricultural and animal wastes) for cooking. About three fourth of households (75.5%) used fuel-wood and only about 7 per cent use LPG in whereas in urban households only one fourth (27.3%) used fuel-wood and majority (63.1%) used LPG.[16] Likewise, Annual Household Survey 2015/16 reported firewood as a major source of cooking fuel in Nepal as more than half (60.9%) are using it. However, the use of LPG gas in urban areas has declined from last year in contrast to the increased consumption of electricity for household purposes. Now in 2015/16, in urban 53.3% are using LPG gas and 37.9% are using electricity which in 2014/15 was 58.3% for LPG gas and 33.0% for electricity.[35] An analysis using data collected in 2013 from three different ecological zones through household surveys revealed that energy security through energy stacking is a dominant phenomenon, biomass fuel being particularly the dominant form of fuel with 84% dependence followed by LPG 9%, biogas 6% and electricity around 1%. The findings also revealed that energy security through energy stacking is a dominant phenomenon.[30] In 2013, An analysis of the patterns of household energy use and associated air pollutant emissions in Nepal based on the LEAP framework for thirteen analytical regions and three end-uses reported that the household sector accounted for most of the energy consumed in the country in the past and this trend is projected to remain the same in next 30 years. With this trend, household energy demand is projected to increase accounting for an increase of 22% or an average growth of 1.1% per year.[36]

Over the last decade, import of cooking energy LPG has increased by 3.3 times as an alternative to kerosene and firewood. Along the growing subsidy burden for the endorsement of modern fuel switching from traditional energy sources and high import requirements of LPG are challenges for energy security and sustainability.[34]

Determinants of Household Fuel Consumption

As supported by existing literature, together with socioeconomic, health, behavioral, cultural, local environment, technologies, availability of fuels, cultural, environmental, cookstove characteristics, government policies and access to infrastructure are the factors affecting household's choice on fuel and adoption of Improved Cooking Stove (ICS).[21] Understanding key determinants of fuel consumption at household level would assist in designing and implementing effective policies to promote access to clean fuel technologies. Evidence has shown that a number of socio-economic factors influence choices for household fuel. Multiple studies find that fuel-wood is chosen by households of all incomes.[37-39] While some studies argue that increase in the income level of the households led to use of multiple fuels rather than completely transition from traditional to modern fuels.[23,25] Different studies have shown income level of the households as one of the important determinants for household fuel choice.[15-18,21,23]

Apart from income, another important factor affecting household choice of fuel is education or awareness. It was found that cleaner energy is more likely to be used in households where the head of the family has a higher level of education especially education level of wife significantly influences the probability of switching from fuel-wood to charcoal or kerosene.[40] Adding to which, studies in Ethiopia and India came up with similar findings that households with more educated members are more likely to choose cleaner fuels.[41,42]

Similarly, another factor influencing the household choice for fuel is pricing. A study in Nepal reported a negative relation between firewood consumption and its price.[30] Similar to this, a study conducted in India in 2010 showed that households tend to depend on traditional fuel despite major share of household income being spent on energy fuel owing to the high price of clean fuel.[43] Likewise, a study of sub-Saharan Africa in 2008 reported high cost of fuel discouraging household from switching to clean cooking fuels.[44] In addition, analysis of data based on household surveys from developing countries in 2011 showed increase in liquefied petroleum gas selection was associated with household expenditure and the highest level of education of household members.[45] However, as study conducted in rural China in 2012 finds that high price of cooking fuel

(coal and LPG) do not result in substitution effects rather it tends to reduce the demand of these energy resources.[46]

Moreover, factors such as the size of the households also influence household fuel choice for cooking. Family size was significantly associated with choice of LPG for cooking in a study conducted in Nepal.[15] Similarly empirical evidence from the developing countries find that household size playing an important role in choice of fuel indicating larger households preferred traditional fuel over cleaner fuels.[11]

Behavioral and cultural factors such as such food taste, cooking practices and cultural beliefs certainly have influence over the household's fuel preferences. Study done on migrants of Guatemala found that migrant households often use traditional ways of preparing foods despite LPG is available and affordable.[39] Similar pattern was observed in India while baking traditional bread as LPG and other sources of fuel as they might alter the original taste of the food being prepared.[46] Even more, this trend was found frequent in the households of rural India with Islamic background.[38] Many social factors and community interactions were found to influence the adoption of alternative sources of fuel. In rural India and Kenya, the decision to choose another cleaner source of fuel was found significantly influenced by the experiences of neighbors and relatives who had adopted the stove.[47,48] Likewise, the opinion of leaders within a community also influences the adoption of ICS in rural Bangladesh.[49,50]

Several other factors such as gender, fuel availability, physical environment and government policies are likely to influence the household choice for fuel. For instance, a study conducted using multilevel longitudinal data from rural Nepal revealed that increased exposure to non-family organizations and services in the local community such as employment, banking, schooling, health care and transportation increased use of alternative fuels.[51] Similar study in rural Southeast China found strong evidence that changes in the livelihoods of rural households (off-farm employment and agricultural specialization) lead to fuel-wood substitution.[52] An example of Indonesia showcased that the most households there are shifting to modern cooking energy through the government's inter-fuel substitution program. Government has been subsidizing households to switch from kerosene, an increasingly expensive fuel choice, to liquefied petroleum gas (LPG).[53] An analysis of micro level data in India found that the gender role differed the choice for household fuel and showed women headed households opted for modern fuels both in urban and rural areas compared to household headed by men.[38] Similarly, a study in rural Bangladesh found women bearing disproportionate cooking costs preferred cleaner fuels over traditional fuel however they lack the authority to make purchases.[49] Likewise, a household survey in Srilanka described two-way interrelation between women earning wages and the transitions to cleaner cooking fuels and technologies.[54] Another important factor impacting household's fuel choice was found to be the availability and easy excess of the source because of which households located far from the market the place also do not choose cleaner energy. Further, the likelihood of using cleaner energy in the mountain and terai regions is less than that in the hilly region.[16]

Despite significant increment in access to clean energy globally, 49% of households in 2000 to 60% in 2016 still, there is a surging necessity to clean cooking fuel as less than two-thirds of households have sufficient access.[6] Evidence also suggests that use of improved stoves led to large percentage and absolute reductions in health problems and implies the needs for a strategic shift towards more rapid and widespread promotion of clean fuels; promotion of the best possible low-emission solid fuel stoves for households still relying on solid fuels.[55]

Health Impacts of Indoor Air Pollution

Though use of any form of energy at home can have various impacts on human health, direct health risks caused by household air pollution from incomplete combustion of fuel is till now the most important.[4]

Global context

Significant quantities of harmful air pollutants and contaminants such as carbon monoxide (CO), polyaromatic hydrocarbons (PAHs), benzene and formaldehyde, and toxic contaminants such as ash, sulfur and mercury are released from incomplete combustion of household cooking fuels, mainly solid fuels.[56] Globally, household air pollution is the leading environmental risk factor for human diseases accounting for 4 million premature deaths and around 5% of lost healthy life years (DALYs).[57,58] The risk of Household Air Pollution (HAP) is mainly concentrated in Africa and Asia regions where households lack access to clean fuel technologies and are still dependent on traditional methods for cooking, heating and lighting purposes. An estimated 500,000 deaths occur from outdoor air pollution caused by household solid fuels used for cooking in developing Asia and Sub-Saharan Africa (SSA) in the year 2010.[59] However, HAP tends to affect women and children globally at most who spend most of their time in the kitchen.[58] Evidence suggests that controlling the exposure of health risks from HAP could reduce the risk of multiple child and adult health outcomes by 20-50%.[55]

Association between indoor air pollution and risk of COPD was observed in the most recent meta-analysis conducted in 2020 which even revealed that the exposure to indoor air pollution from biomass fuel increased the risk of COPD by 2.7 (95% Confidence Interval (CI): 2.1-3.3; n = 73,122) and chronic bronchitis by 2.9 (95% CI: 2.2-3.8) as compared to non-biomass fuels. Higher risk of COPD was depicted mainly in developing regions (Africa, Odds ratio (OR): 3.2 and Asia, OR: 2.9).[60] Similarly, another systematic review conducted to calculate the health risk of COPD from the use of solid fuel found that the exposure to indoor air

pollution (wood smoke) while performing domestic work presented an increased risk of development of COPD (OR=2.8, 95% CI: 1.9-4.0) and chronic bronchitis (OR=2.3, 95% CI: 1.9-2.8) than other fuels.[61] Likewise, Indoor air pollution owing to solid fuel combustion as an important risk factor for COPD in low-income countries, particularly in non-smoking women was reported by a systematic review of literature from particular regions (North America, Europe, Oceania and low-income countries) of the world.[62] India being a close neighboring country of Nepal, they both share similar attributes and even reveals that the non-smoking women there exposed to biomass smoke have death rates from chronic respiratory disease comparable to those of heavy smokers who are males.[63] Household air pollution is also a risk for acute lower respiratory infections (pneumonia) in adults, and contributes to 28% of all adult deaths to pneumonia. One in four or 25% of deaths from COPD in adults in low- and middle-income countries are due to exposure to household air pollution. Near about 17% of lung cancer deaths among adults are contributable to exposure of carcinogens from household air pollution caused by cooking with kerosene or solid fuels like wood, charcoal or coal.[64] Adding to this, poor ventilation or simply inadequate ventilation in China contributed to increase lung cancer risks by 49%.[65]

A comparative study carried out in Trujillo Peru revealed that women cooking with using gas, coal briquette or a combination of fuels have lower creatinine adjusted polycyclic aromatic hydrocarbons (OH-PAH) concentrations compared with those using wood or kerosene.[66] A study conducted in the USA reported that the pregnant mothers exposed to Particulate Matter (PM) 2.5 and black carbon delivered babies with higher systolic blood pressure.[67] A case control survey of mothers who delivered in 2003 in California showed similar results as who were exposed to secondhand smoke at home had higher chances of Low Birth Weight (LBW) [Adjusted Odds Ratio (AOR) = 1.4; 95% CI: 0.9- 2.2) and preterm birth (AOR = 1.3; 95% CI: 1.0- 1.7] in comparison to those who were unexposed.[68] Similar study from India showed that women from households using biomass and solid fuels were twice more likely (OR = 2.2; 95% CI: 1.3-3.9; P = 0.006) to report symptoms of preeclampsia/eclampsia compared to women living in households using cleaner fuels.[69] Another retrospective analytical study conducted in India based on hospital studied the effect of exposure to various kitchen fuels on birth weight showed cooking with wood fuel is a significant risk-factor for LBW.[70]

There is also existing evidence linking household air pollution with increased infant and perinatal mortality, pulmonary tuberculosis, nasopharyngeal and laryngeal cancer, cataract and lung cancer with specific use of coal.[71] Exposure to household air pollution almost doubles the risk for childhood pneumonia and is responsible for 45% of all pneumonia deaths in children less than 5 years old.[3] HAP is also known to increase oxidative stress which plays an important role in increasing insulin resistance and is associated with decreasing the mobility of sperm and quality of zygote leading to decreased fertility or even infertility.[72] Endocrine disrupting chemicals known to have profound effects on endocrine system are present in different forms in indoor air, can interfere with hormonal actions either by altering hormone synthesis or through altering transport of the hormone or by competing for binding to carrier proteins. They are linked to a range of human health issues including insulin resistance, reproductive and developmental abnormalities, endocrine cancers, thyroid and adrenal dysfunction, immune dysfunction, and disorders of energy metabolism. However, instances relating endocrine abnormalities with airborne source of EDCs directly are few in number.[73]

WHO generated evidence have also illustrated that the exposure to household air pollutants confer an increased risk for deaths due to cardiovascular diseases. Exposure to 12% of all deaths due to stroke can be attributed to the daily exposure to household air pollution arising from cooking with solid fuels and kerosene. Nearly 11% of all deaths due to ischaemic heart disease, accounting for over a million premature deaths annually, is also attributed to exposure to household air pollution.[3] A meta-analysis performed in China showed short term exposures to PM10 and PM2.5 is likely to be associated with the increase in the risk of mortality for cardiovascular diseases. Cardiovascular mortality is increased by 0.36% and 0.63% with a 10 μg/m 3 increase in indoor PM 10 and PM 2.5 respectively.[72]

Nepalese context

Indoor air pollution is prevalent in more than 80% of the households in Nepal.[74] Approximately 70% households here in Nepal are built using wood and mud with inadequate ventilation making them more susceptible to IAP.[75] As illustrated by the ventilation analysis result, a staggering more than 80% are still deficient in ventilation as per the minimal rate of ventilation defined by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Moreover, the placement of chimney at a short vertical height of 1.2 m adjoining the back window is the major cause of backflow. Therefore, the study has recommended a greater focus on ventilation to control IAQ of rural mountainous households.[76]

In the context of Nepal, 7500 annual deaths contributing to 2.7% of national burden of diseases is attributed to use of solid fuel.[29] Nepal has higher prevalence of respiratory symptoms and reduced lung function associated with solid fuel use both in children and in adults, particularly in females involved in cooking.[61] A qualitative study conducted in southern Nepal on women identified a number of health effects from air pollution with the main effects being on the physical health related to the eye and the respiratory system and reported modifications to the cooking process, changing the location of stoves, and increasing ventilation as solutions to the problem.[77] Respiratory health adversities

are found more prevalent as well as common among the household that lacks proper ventilation/chimney for the efficient air circulation.[78] A cross-sectional study on health impact of indoor air pollution to exposed kitchen dwellers and children conducted in Nepal identified a significant association between exposure to IAP and prevalence of respiratory disorders and related symptoms among adults and children.[27] Similarly, in 2016, a cross-sectional study in Ilam district of Eastern Nepal reported respiratory illness and deficit in lung function linked with indoor air pollutant parameters.[79] Likewise, a study from Nepal reported use of solid fuel increased the risk for Acute Respiratory Infection (ARI) among children under five years of age by two times compared to children from households using cleaner fuels and concluded it as an important predictor.[80] One of the case control study conducted among a population in the Bhaktapur municipality, Nepal, to investigate the relationship of cooking fuel type to Acute lower respiratory Infection (ALRI) in young children supports that the use of biomass as a household fuel is a risk factor for ALRI, and provides new evidence that the types of kerosene and kerosene stoves used in Nepal for cooking may also be a risk factor for ALRI in young children.[81] Similar cross-sectional study of adults exposed to biomass smoke and a non-exposed population in Nepal, found strong association with deficits in lung function, an effect that can only be detected as early as the late teenage years. Further, it revealed that the biomass smoke and cigarette smoke have additive adverse effects on airflow obstruction in those settings.[61]

CONCLUSIONS AND RECOMMENDED RESEARCH GAPS

In the present context of Nepal, studies have been conducted in rural areas however questions arise around generalizability of the studies owing to different study designs. Several factors such as socioeconomic, health, behavioral, cultural, local environment, technologies affect the household's choice for adopting clean fuel technologies. These factors affecting fuel consumption at household level should be considered in designing and implementing policies supporting access to clean fuel technologies. Based on our review of evidence, indoor air pollution tends to have numerous effects on health, in particular affecting women and children who spend longer hours in the kitchen. Health effects of household air pollution focusing women and children should be considered while formulating policies in regard to reducing household air pollutants. Also, in Nepal many governments, multinational companies and nongovernmental organizations are developing programs to promote access to improved stoves and clean fuels, but there is little demonstrated evidence of health benefits from most of these programs or technologies in comparison to traditional fuels.

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