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Review Article

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INDOOR AIR POLLUTION AND ACUTE RESPIRATORY INFECTION AMONG CHILDREN: AN UPDATED BIOMASS SMOKE

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ABSTRACT:

One - third of the world's population burn organic material such as wood, dung or charcoal (biomass fuel) for cooking, heating and lighting. This form of energy usage is associated with high levels of Indoor Air Pollution (IAP) and an increase in the incidence of of ARI in children. Acute respiratory infections (ARI) are a leading cause of children illness and death in developing countries. Due to the fact that, most of time training of children in internal environments. There is consistent evidence that indoor air pollution increases the risk of acute respiratory infections in children, and the most important cause of death among children under 5 years of age in developing countries. Exposure to biomass smoke and risk of acute respiratory infections in children has been examined in a lot of studies. Previous reviews were limited in scope, evaluating only outcomes exposure biomass smoke and prevance ARI children. Hence, with important evidence accumulating, there is a need to improve the previous awareness correlated with various interventions to reduce indoor air pollution (IAP) in many countries. This study conducted a systematic review to evaluate the effects of biomass smoke on the incidence of ARI in children and interventions to reduce indoor air pollution with highlight recent years' studies in developing countries. The results have indicated that exposure to biomass smoke increasing prevalence of ARI in children (rang; 1.00 -3.89 (CI 95% 0.92 – 28.25); median =1.99). Our findings suggest that in addition to promoting increased access to stove improving technologies there are one important organization and micro environment related interventions that dropped IAP exposure. It was expected that this results were useful for the impact on the public argument and policies at the national level in future to improve the quality of indoor air to reduce the burden of disease caused by acute respiratory infections in children.

REVIEW

Acute respiratory infection (ARI) is the most common cause of illness in children and a major cause of death in the world [1]. Among children under five years of age, three to five million deaths annually have been attributed to ARI [2], with about 40 % of these deaths happening in Africa and about 30 % in southeast Asia [3]. ARI

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generally divided into two main forms: upper respiratory tract infections (AURI) and lower respiratory tract infections (ALRI), depending on the key organs affected (nose, sinuses, middle ear, larynx and pharynx versus trachea, bronchi and lungs) [4]. Air pollution, including indoor and outdoor sources, contributes to more than 2 million premature deaths annually [5, 6]. Generally, harmful effects of air pollution is recognized to increase cardiovascular diseases [7]. All through the last decades research all over the world has underlined the harmful effects of outdoor and indoor pollution on respiratory health of adults and children [8]. Outdoor air pollution has long been considered a considerable concern for human health. But, there has been a growing awareness that IAP is of equal or greater impact to human health. The reasons for this can be listed as follows: 1. the amount of time people spend indoors 2. the wide and varied range of indoor emission sources 3. the increased concentration of some pollutants indoors compared with outdoors. Generally, IAP is not only an important environmental health issue on the world [9]. Furthermore, indoor air pollution is a major cause of the third leading contributor to global disease burden, and the highest in South Asia [10].

Indoor sources of air pollution can be resulted from combustion processes for cooking and heating; from human activities, such as smoking, presence of biological agents, and use of chemical materials; and from releases of building materials and radon [11]. Indoor air pollution exposure has been associated with a ALRI for example pneumonia among young children in developing countries [12, 13]. On the other hand, exposure to indoor air pollution has 2.3 (1.9 - 2.7) times increased risk of respiratory infections especially ALRI [14]. The key risk factors for morbidity from ARI in childhood in developing countries are thought to be low socioeconomic status, malnutrition, low birthweight, lack of breastfeeding, crowding and indoor air pollution [15].

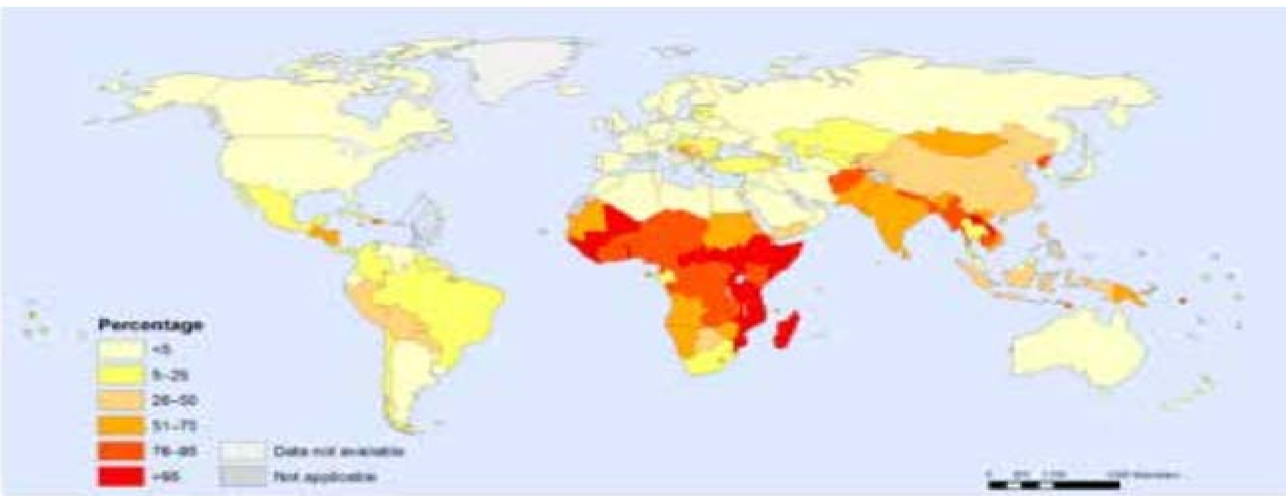
Biomass fuel is the key source of IAP can lead to the high burden of illness and death from acute respiratory infections in children relation to indoor biomass combustion product exposure in developing countries [16 - 18]. It is estimated that between one - third and half of the world›s population use biomass as a source of energy with more than 90 % of subjects in rural areas of less developed country's using biomass fuels (BMFs) [19]. Acute respiratory infection, one of the leading diseases that accounts for more than 6 % of worldwide morbidity and mortality, has been found to have positive exposure – response relations with domestic biomass burnings [20]. The result of meta-analysis study suggested that children were at least three times more likely to develop ARI when exposed to biomass fuel compared with alternative fuel (OR 3.53, 95 % CI 1.94 to 6.43) [21]. Biomass materials are considered low - efficiency fuels [22, 23]. Inefficient burning of BMF an open fire or traditional stove generates large amounts of toxic products. Thus, it yields relatively high levels of products of incomplete combustion, which are more damaging to health [7]. This pollution use is a significant risk factor for acute respiratory infection [24]. Exposure to household air pollution is not only an environmental risk associated with respiratory disease for a large part of the world's inhabitants but also a confirmed risk factor for ALRIs, especially in children, in developing countries [22, 25, 26]. Furthermore, large study was investigated about exposure to household air pollution and number of health outcomes, most notably and ALRI. In fact, in current study, the original study and review and meta - analyses were updated to provide estimates of the effect of indoor air pollution on ARI in infants with special focus on developing countries. In addition, based on the findings, the study gives strategies to reduce or eliminate continued exposure and better scientific understanding to the community of the future predictions and also helps to take essential steps for the safe use of biomass.

Biomass fuel

Indoor fuel sources can be any solid, liquid, or gas combustibles, with biomass fuel and coal constituting by far the most frequently used solid fuels. Biomass fuel refers to animalor plant derived material products (wood, agriculture waste, and dung) burned for cooking or heating purposes [27]. On a global scale, the household use of solid fuels is the most important source of indoor air pollution [22]. Fig. 1, shows the global size of solid fuels for cooking. Well into the 21st century, 2.8 billion people still depend on solid fuels, more than 95 % of the population uses solid fuels for cooking in a significant number of countries, most of which are in sub - saharan Africa.

Biomass fuel is one of the solid fuels that in developing countries, households often continue to use simple biomass fuel. Around 2.4 billion people depend on BMF as their main source of domestic energy for cooking, heating and lighting [7]. Ranging from near 0 % in developed countries to more than 80 % in China, India, and sub-Saharan Africa. In the rural areas of Latin America, around 30 to 75 % of households use biomass fuels for cooking [22]. Cooking and heating is the most important activity contributing to indoor air pollution. However, in some regions, especially in Asia, heating is another important source [19, 22].

Exposure to BMF smoke is the highest among young children spend more time indoors with mother. BMF smoke plays a contributing role in mortality from lower respiratory tract infections among children living in homes where BMFs are used especially for developing countries [19, 29]. In agreement, important the exposure - response relation between indoor air pollution from biomass combustion and ARI in children. This section will describe the extent of indoor air toxic pollutants factors and mechanism of these factors that influence exposure to IAP and the health impacts of such exposure.



Source: WHO (5)

Fig. 1. Percentage of population relying on solid fuels as the primary cooking fuel in 2012, by country [28]

When these fuels burn in simple cook stoves during meal - preparation, the consequence of this is a high burden of IAP consisting of toxic pollutants, including volatile organic compounds (VOCs), particulate matter (PM), carbon monoxide (CO), and oxides of nitrogen, sulfur and fluorine, volatile organic compounds, chlorinated dioxins, free radicals and polycyclic aromatic hydrocarbons (PAHs). Of these pollutants, PM and CO have been monitored most usually in homes that depend on biomass fuels [20, 30 - 32]. This pollutants fromburning biomass fuel be able to enter deep into the lungs and produce various morphological and chemical changes in the respiratory tract, increasing susceptibility to infections [33].

Mechanisms by which some key pollutants

The mechanism by which fuels burn can increase the risk of ARI is not fully understood. Exposure to biomass smoke has been associated with the compromise of pulmonary immune defense mechanisms. and signs of increased oxidative stress in the respiratory tract, especially in the lower airways.

PM and CO

The adverse effects of indoor PM are dependent on deposition in the respiratory tract and the ability of the respiratory tree to remove them, which is directly related to particle size and chemical composition [34]. There is much research focus now on $PM_{2.5}$ released from biomass smoke. This size fraction can penetrate deep into human lungs making it a major health risk [35]. This is one of the most hazardous pollutants emitted by solid fuels; its concentration increases to mg / m^3 inside kitchens during cooking well above the guidelines [6]. CO is a main source are combustion processes from biomass burning [36]. CO binding with affinity that is about 200 –250 times greater than that of oxygen, there by harming hemoglobin's ability to transport oxygen to key organs around the body and leading to tissue hypoxia and damage [22, 30]. Typical 24 h concentration levels of PM_{10} (particulate matter less than 10 μm in diameter) in the majority of rural households in developing countries such as: African, Asian, or Latin American homes using biomass fuels range from 300 to 3,000 μg / m^3, and it has been provided that peak levels during active cooking in these regions may also be as high as 10,000 μg / m^3 [10, 30].or 30,000 mg / m^3 [37]. The mean 24 h levels of CO in the same households are in the range of 2 to 50 ppm, and can may be 500 ppm during cooking [22].

A study in Nepal conducted that 96 households were using solid biomass fuel as a primary source of fuel, the average smoke level (PM_{10}) in kitchens using biomass fuels was about three times higher than that in those using cleaner fuels as: kerosene, LPG, and biogas [38]. Furthermore, $PM_{2.5}$ and CO levels in the households of Gambian, and the exposures of children to $PM_{2.5}$ is well above WHO air quality guideline [39].

PAHs and NO

PAHs are account environmental pollutants with toxic and carcinogenic properties, this pollutants are included in the list of hazardous air pollutants by the US Environmental Protection Agency (USEPA). The emission level of pollutant PAHs (mostly Benzo(a)pyrene (BaP)) are especially high during cooking times. Such as, total PAHs concentration during cooking and non cooking periods were 6.21 μg / m^3 and 1.41 μg / m^3 respectively [35]. Other evidence indicates that exposure to PAHs, which is found in large quantities in biomass smoke can cause immune suppression and can increase the risk of infection and disease [1, 40]. In a study, Taylor et al showed concentrations of PAHs, PM and CO were higher than the WHO recommended guidelines which raise concern with regards to health risk [35]. Furthermore, exposure to indoor air pollution, especially to nitrogen monoxide from the combustion of biofuels (wood, charcoal, agricultural residues, and dung) has been implicated to irritant, affecting the mucosa of eyes, throat, and respiratory tract. also, increased bronchial reactivity and in longer - term exposure increases susceptibility to infections [11].

Formaldehyde and organic pollutants

Formaldehyde is recognized as an acute irritant that long - term exposure to it can cause a reduction in vital capability and chronic bronchitis. The mean levels of formaldehyde released from cattle dung, wood, coal, kerosene, and LPG (670, 652, 109, 112 and 68 µg / m^3) respectively, have been calculated [41]. This indicated the level of this pollutant is high on the biomass fuel compared to the other fuels.

Organic pollutants can adsorb onto the surface of PM, contributing to important adverse health effects such as certain heavy metals and persistent organic pollutants, on the development of the nervous system and behavior in children [42]. Several guidelines for exposure limits for indoor air contaminants have been developed (Table 1).

Exposure by toxic pollutants for indoor biomass fuel and ARI, ALRI in children

Table 2. Showed differences epidemiological data of increased risk of ARI, ALRI in children and exposure biomass fuels in world especially in developing countries. Results are presented in the form of odds ratios (OR) with 95 % CI.

According to Table 1, exposure with biomass fuels was recognized as a cause of lower respiratory infection in children. In need, resulting increasing risk lower respiratory infection and acute respiratory infection in children with OR in rang 1.00 - 3.89 (95 % CI; 0.92 – 28.25). In agreement with our study, a systematic reviews of biomass fuels exposure and ARI risk among young children in developing countries found a significant association with ARI and ALRI morbidity and mortality (OR; range: 1.6 -3.53

Table 1. Recommendations for indoor air quality

Contaminant	Recommended
$PM_{2.5}$	Short - term exposure: 100 µg / m^3 per 1 h (A) Long - term exposure: 40 µg / m^3 (A) 25 µg / m^3 / 24 h (average) (C)
PM_{10}	150 ppm / 24 h (average) (B)
CO	11 ppm / 8 h (average)(A) 25 ppm / 1 h (average)(A) 10 ppm / 8 h (average) (B)
NO	Short – term exposure: 480 µg / m^3 (0.25 ppm) per 1 h (A) Long - term exposure: 100 µg / m^3 (0.05 ppm) (A)
Formaldehyde	50 µg / m^3 (40 ppb) for 8 h exposure (A) • 123 µg / m^3 (100 ppb) for 1 h exposure (A)

[A] health Canada recommendations for indoor air quality [36]

[B] The United States Environmental Protection Agency's standards [43]

[c] World Health Organization (WHO) [6]

Table 2. Summary of studies reporting on ARI and ALRI of household biomass fuel combustion

Population (year)	Adjusted incidence Odd's ratio (95 % confidence intervals)	Odd's ratio (95 % CI)	Ref
4,802 Children (< 5)	age, sex, birth order, urban / rural residence, ecological zone, development region, economic status, number of family members, mother's smoking status and mother's education	1.79,(95 % CI 1.02, 3.14)	[44]
3559 Children (age 0–59 months)	age, sex, birth order, nutritional status, mother's age at childbirth, education, religion, household living standard, and region of residence	3.89, (95% CI: 1.54, 28.25)	[1]
422 Household with children (< 5)	sex, smoking, ventilation, child handling behavior	2.97, (95% CI: 1.38-3.87)	[45]
1173 children (< 5)	time trends and potential confounders	1.33, (95% CI: 1.02–1.73)	[46]
917 Children (452 cases and 465 controls)	Secondary stove fuel, Child in kitchen during cooking, Space heating in winter, Usual kitchen ventilation	1.45,(95% CI: 0.97- 2.14)	[47]
257 Children	aged 0 – 11 months, known confounders	(IRR) 1.07, (95% CI: 1.01-1.14)	[48]
	12 – 23 months old, known confounders	1.00, (95% CI 0.92–1.09)	
520 Children (<5)	age, sex, number of siblings, exposure to biomass smoke and exposure to tobacco smoke, separate kitchen, house type and number of rooms	For charcoal fuel 1.14,(95% CI: 0.71–1.82)	[26]
		For wood fuel 2.03, (95 % CI:1.31–3.13)	
29,768 Children (age 0 – 35 months)	environmental tobacco smoke (ETS)	1.82, (95 % CI: 1.58 - 2.09)	[49]
5224 children (< 5)	child's sex, age and place of residence; mother's education, mother's age at child birth and household living standard,	1.19, (95% CI: 0.92 - 1.54)	[50]
17,780 Living children	-	2.19, (95% CI: 1.37–3.51)	[51]
609,601 Living children	age (in years), rural/urban, type of house, education of the head of the household, latrine type and number of siblings	Boys, PR 1.54, (95 % CI :1.01 - 2.35) girls, PR 1.94 (95% CI: 1.13 - 3.33)	[52]
32,620 Children	child sex as well as wealth and maternal education as at least partly independent socioeconomic confounders	2.35, (95% CI: 1.22 - 4.52)	[53]
3559 Children (age 0-59 months)	child's age, sex, birth order, nutritional status, mother's age at childbirth, education, religion, household living standard, and region of residence	2.20,(95 % CI: 1.16 - 4.19)	[40]
204 Infants	-	1.77,(CI 95 % : 1.27 - 2.46)	[54]

[a] OR - Odds Ratio; RR–Relative Risk; CI - Confidence Interval; PR - prevalence ratio

with 95 % CI; range: 1.53 - 6.3) [21, 55, 56]. Significantly greater rates of ARI have also been observed among children age group 6 - 11 months old. Although many opinion exiting for higher effect in this age group. But, it can additional be urged that unlike their younger counterparts, children in this age group are old enough to be carried on their mothers' back which may increase the probability of exposure to smoke while their disease resistance system is less developed than their older counterparts leading to higher ARI rate [33, 50]. In the cross-sectional study was conducted in Pakistan, found that use of biomass fuel was associated with increased incidence of ARI among children. In fact, in houses where fossil fuel can be used to cooking , those children's often carried or in lap during cooking were 2.68 times more likely to suffered from ARI than their counterparts (rate ratio (RR) 2.68; 95 % CI: 1.5 - 4.5) [33].

Suggestions for prevention of diseases associated to solid fuel smoke exposure

Health risk associated by solid fuel smoke exposure differs with housing and ventilation, energy that used for technology (an example of this; tripod, oven, stove), pollutant concentration in the close breathing environment and the time spent in the environment. Interventions to reduce indoor air pollution contain developed stove quality and behavior change, such as better fuel selection and opening windows for better ventilation [5]. Reviewing the studies conducted over two decades up to 2013, finds the evidence on the effectiveness of behavior change interventions on HAP to be weak [57].

Improvements in ventilation and stoves

Ventilation rates for houses in developing countries, which discovery primarily in tropical and subtropical regions of the world and are often open to the outdoors, are likely to be greater [2]. If children could be in a clean environment at acute times of the day, such as early evening when cooking is taking place, their exposure would be reduced [10]. Stove intervention projects or programs include for example, changes in stove or heating apparatus, changes in ventilation arrangements and changes in behavior geared towards reducing emission and exposure to cooking smoke have been conducted in different parts of the world in recent years to reduce human exposure to IAP [20, 31]. Another simple intervention is replacing the traditional open fire with an improved cooking stove that can reduce IAP by almost 50 %, making it a usually supported intervention [30]. Replacing the traditional open fire with more efficient cooking technologies has long been an option to reduce indoor air pollution, as well as to decline fuel consumption, greenhouse gases emissions [29]. Parajuli et al and Yip et al investigated CO and $PM_{2.5}$ pollutant concentration in households with improved cooking stove and traditional cooking stove separately at Nepal and Kenya respectively. The findings of in two study show that improved cooking stove is better in comparison to traditional cooking stove operation in respect to concentration [58, 59].

Several studies have also shown that improved solid fuel stoves can provide significant reductions in kitchen levels and child exposure but, since other studies have shown minimal or no reduction even in kitchen air pollution levels, it is important not to accept that a stove described as "improved" will really reduce child exposure unless so established. Putting in of an improved Patsari stove in 60 homes in a rural community of Michoacan, Mexico resulted in 74 % reduction in median 48 h $PM_{2.5}$ concentrations in kitchens and 35 % reduction in median 24 h $PM_{2.5}$ personal exposures. Resultant reductions in CO were 77 % and 78 % for median 48 h kitchen concentrations and median 24 h personal exposures [60]. Chimneys directing the fumes to the outside of the household can be added and enhance the benefits in reducing the particulate indoor air pollution. Reductions from 40 to 85 % in $PM_{2.5}$, PM_{10}, and CO concentrations and a reduction by 24 to 64 % of acute respiratory infections and 21 to 44 % for ALRIs in children younger than 5 years in, have been described using improved stoves [22]. Nevertheless, Mortimer and colleagues did not find a difference in the incidence of acute lower respiratory tract infections in 10,750 children from 8,626 households randomized to have biomass - fueled cook stoves with improved ventilation when compared with a traditional open - fire cook stove [61]. Moreover, the use of improved ventilated stove are the most important interventions to decrease impact on health [23]. But, in poor household more reducing the adverse health impact of exposure to smoke from biomass fuel is the simple cooking related applies that increase ventilation [62]. Also, having either doors or windows open during cooking but not both decreasing risk ALRI in children [47]. Higher proportion of ARI was seen among 272 children having no smoke outlet in their houses [14]. In the cross - sectional study was conducted in India, among 397 school children between of 5 - 14 years, the major association found between absence of windows in sleeping room with ARI (OR = 3.0) [63]. Table 3, referred to recent interventions study's that evaluated impact of improved stoves, house ventilation on levels of indoor air pollution and child exposure on biomass fuel.

Table 3. Characteristics of studies impact of improved stoves, house ventilation on levels of indoor air pollution and child exposure on biomass fuel

Papulation	Fngindi	Conclution	
204 Households with children less than 18 months	The 24 h kitchen CO was lowest for homes with self-purchased plan Chas for open fires. The same ranking was found for child CO exposure, The predicted child PM for all 203 children was 375 mg / m^3 (270 – 480) for self-purchased plan Chas and 536 mg / m^3 (488 – 584) for open fires	The improved stoves have been effective in reducing indoor air pollution and child exposure, although both measures were still high by international standards	[64]
10 750 Children from 8626 households (intervention group)	Incidence rate in the intervention group was 15·76 (95% CI 14·89 –1 6·63) per 100 child-years and in the control group 15·58 (95% CI 14·72 – 16·45) per 100 child - years	No evidence that an intervention comprising cleaner burning biomass-fueled cook stoves reduced the risk of pneumonia in young children in rural Malawi	[65]
10543 Children from 8470 households (control group)			
Accost effectiveness analysis	Improved stoves are also much more cost-effective than cleaner fuels		[66]
60 Households	Improving cooking devices and indoor ventilation reduces the part of ARI in children under 5 years attributable to exposure to biomass smoke, but a higher reduction is achieved by cooking outdoors		[62]
534 Households with a pregnant woman or young infant (269 woodstove with chimney and 265 using open wood fires (control group)	Recorded significant reductions in the intervention group for severe outcomes pneumonia		[67]

Changes of the fuels for cooking and heating

Replacing biomass fuels used for cooking or heating with cleaner fuels, such as petroleum - derived fuels (LPG, kerosene), industrially processed biomass, thermoelectric energy, electricity, and, eventually, nuclear energy, may solve the health problems related with exposure to biomass smoke [40, 68]. As Pokhrel et al showed the mean kitchen $PM_{2.5}$ concentrations in μg / m^3 associated with the 4 primary stove types were 80 (electric), 101 (gas), 169 (kerosene) and 656 (biomass) [69]. Alemayehu et al investigated 715 children age 0 – 59 months in Gondar city of Ethiopia. Results support that children in households using wood, dung, or straw for cooking were 3.89 times more likely to have suffered from ARI as compared to children from households using LPG or electricity (OR = 3.89; 95 % CI: 1.54, 28.25) [1]. In addition, In study Naz et al estimated the risk of under - five mortality was approximately 30 % higher in the polluting fuel group compared to clean fuel group [70]. Capuno et al showed that that the household use of clean fuel for cooking can reduce the risks of respiratory illness in children below five years in the Philippines, In such a way, that use of electricity, liquefied petroleum gas, natural gas or biogas can lower by 2.4 percentage facts the incidence of severe coughing with difficulty in breathing in young children, and, support worldwide initiatives to promote the household use of clean fuels for cooking and heating to reduce HAP and its undesirable impacts on children [65].

In contrast this results for electricity and LPG, kerosene fuel has also been found to be harmful to health [65]. Alternatively, as the authors speculated, this difference may highlight the potential that kerosene smoke is more pathogenic than firewood smoke. Kerosene is a similar petroleum distillate to diesel, and kerosene smoke is likely to be more toxic than biomass smoke [71]. If so, then it may be due to finer particulates from kerosene reaching further into the lungs or it may be something to do with composition of the kerosene particulates, or a combination of the two [72]. Choi et al, found kerosene cooking was related with respiratory conditions, including bronchitis, children in Bangalore, India, but did not specifically address ALRI [73]. But, Bates et al showed that biomass and kerosene cooking fuels are both ALRI risk factors [72]. A case–control study was conducted among a population in the Bhaktapur municipality, Nepal, to study the relationship of cook fuel type to ALRI in young children use of wood, kerosene, or coal heating, ALRI was increased in association with any use of biomass stoves OR; 1.93(95 % CI: 1.24 - 2.98), kerosene stoves (OR; 1.87(95 % CI: 1.24 - 2.83), and gas stoves (OR = 1.62; 95 % CI: 1.05, 2.50). Also, study supports previous reports indicating that use of biomass as a household is a risk factor for ALRI, and provides new evidence that use of kerosene for cooking may also be a risk factor for ALRI in young children [47]. Easy scenarios for rates of change from mainly traditional solid fuel use for cooking in the home to low - emission improved solid fuel stoves, clean fuels in world by WHO (Fig. 2) [28]. Considering the Fig. 3, using from clean fuel in rural poor is not only difficlut, but also, in the long time not exist. Consequently, For households continuing to rely on solid fuels stove, intervention programs have been recommended in different parts of the world reduce human exposure to IAP [74] .

CONCLUSIONS

ARI are the leading cause of childhood illness and death worldwide. Exposure to indoor air pollution from biomass fuels has been found to be important cause of ARI chidren in the world.

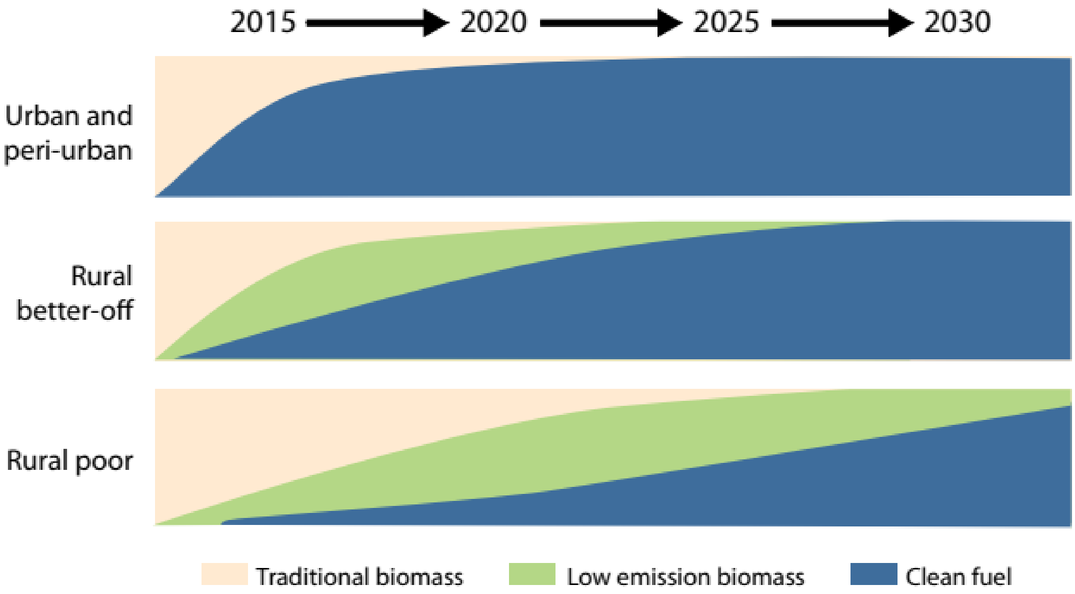


Fig. 2. Hypothetical, simplified scenarios for rates of switch from predominantly traditional solid fuel use for cooking in the home to low-emission improved solid fuel stoves, clean fuels in world [28]

In developing countries where solid fuel usage is the most important, the use of biomass fuel is very common. This study found that use of biomass fuel was associated with increased incidence of ARI among children. Results showed for the association between use of biomass fuel and ARI high incidence are (up to OR:3.97, 95 % CI; 0.92 – 28.25). Consequently, to reduce the incidence of ARI and associated morbidity and mortality, short term interventions such as use of effective stoves about keeping children away while cooking would be useful. In the long term, strategies should be advanced for changing to cleaner fuels including LPG and electricity with low pollutant, which may require investment in setup as well as economic development. The findings from this study have important policy and program implications, in the preventive perspective for sustainable development; there is need for interventions that replace biomass fuels with more processed and cleaner fuels.

LIST ABBREVIATIONS

IAP: Indoor Air Pollution
ARI: Acute respiratory infections
ALRI: Acute lower respiratory tract infection
AURI: Acute upper respiratory infections
BMF: Biomass fuels
$PM_{2.5}$: Particulate matter with a diameter of 2.5 mm or less
PM_{10}: Particulate matter with a diameter of 10 mm or less
NO_2: Nitrogen dioxide
NO: Nitric oxide
PAHs: polycyclic aromatic hydrocar - bons
OR: Odds ratio
RR: Relative risk

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COMPETING INTERESTS

No potential conflicts of interest relevant to this article were reported.

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ETHICAL CONSIDERATIONS

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and / or falsification, double publication and/ or submission, redundancy, etc.) have been completely observed by the authors.

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