ARTICLE

Impact of Improved Cooking Stoves on Reducing Household Air Pollution and Improving Health among Nepalese People: A Systematic Review

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ABSTRACT

Household air pollution (HAP) is generated by the use of inefficient and polluting fuels and technologies in and around the home that contain a range of health-damaging pollutants. Major pollutants associated with household air pollution include particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO2), volatile organic compounds (VOCs), and various other harmful gases and chemicals. Yet, while there exists extensive literature on improved cooking stoves, the evidence remains unclear regarding ICS intervention status and its impact on health and the environment especially in Nepal. We conducted a systematic review of the research evidence on the Impact of improved cooking stove (ICS) interventions on the reduction of household air pollution, fuel wood, and positive health effects in Nepal. Article selection was conducted through title screening, abstract screening; and full article screening, following the Population, Intervention, Control, and Outcomes (PICO) criteria. For search platforms, we included Google, Google Scholar, Research Gate, PubMed, and Cochrane. The inclusion criteria were studies that were published between 2000 to 2023 AD. Comparison between ICS post-intervention values of HAP, energy efficiency, and impact on health with the baseline values, which correspond to traditional cookstove (TCS) use through before and after design. Results indicate that PM2.5 and CO concentration was significantly lowered in ICS use as compared with TCS. The intervention stove demonstrated significant wood savings, lowering the emission of household air pollutants and improving the health status. In addition, findings suggest a need to provide the proper training to local people about the installation, use, and maintenance of stoves and the need to cost sharing with local government and households for the sustainability ICS program in Nepal. Furthermore, findings suggest that efficiently burning stoves should be designed technically, using locally available sources which makes affordable and culturally acceptable ICS programs.

Household air pollution is generated by the use of inefficient and polluting fuels and technologies in and around the home that contain a range of health-damaging pollutants. Major pollutants associated with household air pollution include particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO2), volatile organic compounds (VOCs), and various other harmful gases and chemicals. Household air pollution is caused largely by the burning of polluting fuels such as wood, animal dung, charcoal, agricultural waste, and kerosene in open fires or inefficient stoves in and around the household (WHO, n.d.).

South Asia suffers from extreme air pollution. Of the world's 10 cities with the most severe air pollution, 9 are in South Asia. Exposure to extreme air pollution has severe health impacts. Current air pollution is estimated to cause more than 2 million premature deaths each year in South Asia. Exposure to PM2.5 in 2030 comes from HAP from burning solid fuel, in 71% of households in Nepal, 60 % in Sri Lanka, and 45 % in Bangladesh and Pakistan. In India, 40% of households are on the Indo-Gangetic Plain. The number of those exposed is greatest on the Indo-Gangetic Plain, in Bangladesh, and in the Punjab and Khyber regions of Pakistan. The additional exposure to PM2.5 due to indoor air pollution is more than twice the level of ambient exposure in all major South Asian regions (World Bank, 2023).

Sources of energy use

The global population lacking access to clean cooking fell from 2.9 billion in 2010 to 2.3 billion in 2021, but the goal of universal access by 2030 remains elusive. 1.9 billion people would still be without access to clean cooking in 2030. around 2.3 billion people still cook using solid fuels (such as wood, crop waste, charcoal, coal, and dung) and kerosene in open fires and inefficient stoves. Most of these people are poor and live in low- and middle-income countries. There is a large discrepancy in access to cleaner cooking alternatives between urban and rural areas: in 2021, only 14% of people in urban areas relied on polluting fuels and technologies, compared with 49% of the global rural population. The world is not on track to achieve universal access to clean cooking by 2030 (IEA, IRENA, UNSD, World Bank, WHO, 2023).

In Nepal, 96% of households have access to electricity (98 in Urban areas and 94 in Rural areas). Overall, 41% of the population lives in households that use clean fuels and technologies for cooking, with the percentage much higher in urban areas (53%) than in rural areas (19%). Fifty-eight percent of the population lives in households that use solid fuels for cooking (81% in rural areas and 47% in urban areas). Wood is the most common solid fuel (49% of households) which is used more frequently in rural areas (72%) than in urban areas (37%) (Shah, 2023).

Household air pollution impact on health

Globally, cooking with open fires or simple three-stone stoves fueled by kerosene, coal, and biomass such as wood, dung, and agricultural residues. When people are exposed to household air pollution levels above the WHO air quality guidelines, they are at increased risk of health impacts, in particular cardiovascular and respiratory diseases and lung cancer, cataracts, and adverse pregnancy outcomes (WHO, 2022). According to WHO (2022), 3.2 million deaths are attributable to household air pollution created through the use of polluting fuels and technologies for cooking. Among these 3.2 million deaths from household air pollution exposure. 32% are from **ischaemic heart disease:** 12% of all deaths due to ischaemic heart disease, 23% are from **stroke:** approximately 12% of all deaths due to stroke, 21% are due to **lower respiratory infection:** exposure to household air pollution almost doubles the risk for childhood LRI and is responsible for 44% of all pneumonia deaths in children less than 5 years old similarly acute lower respiratory infections in adults and contributes to 22% of all adult deaths due to pneumonia and 19% are from **chronic obstructive pulmonary disease (COPD):** 23% of all deaths from chronic obstructive pulmonary disease (COPD) in adults in low- and middle-income countries and 6% are from **lung cancer**: approximately 11% of lung cancer deaths in adults are attributable to exposure to carcinogens from household air pollution (WHO, 2022)

Cooking with solid fuels in inefficient stoves often results in high levels of indoor air pollution in South Asia and suffers from extreme air pollution. Exposure to extreme air pollution has severe health impacts. Current air pollution is estimated to cause more than 2 million premature deaths each year in South Asia. PM2.5 is now also understood to be an important causative factor in many non-communicable health risks. PM2.5 is associated with chronic obstructive lung disease, ischemic heart disease, lower respiratory infections, lung cancer, strokes, and type 2 diabetes (World Bank, 2023.)

Projection of premature deaths in 2030:

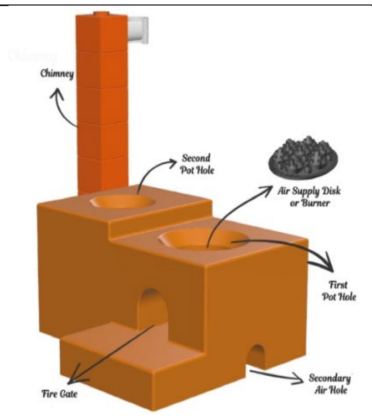
Air pollution is projected to account for 2.1 million premature deaths in 2030 in the five South Asian countries. Premature mortality associated with PM2.5 is estimated for chronic obstructive lung disease, ischemic heart disease, lower respiratory infections, lung cancer, strokes, and type 2 diabetes. Deaths attributed to PM2.5 account for a significant fraction of total deaths in each country: 20 percent in Bangladesh, 15 percent in India, 18 percent in Nepal, 17 percent in Pakistan, and 11 percent in Sri Lanka. In Bangladesh, India, and Pakistan, ambient air pollution accounts for about two-thirds of PM2.5 deaths, while HAP accounts for one-third. The reverse is true in Nepal and Sri Lanka, where ambient PM2.5 levels are, on average, lower and exposure to HAP higher (World Bank, 2023.)

Yet, while there exists extensive literature on improved cooking stoves, the evidence remains unclear regarding ICS intervention status and its impact on both health and the environment, especially in Nepal. There is a need to synthesize the evidence of importance of the ICS use and its impact on health as well as the environment. Additionally, Scientific evidence concerning the effectiveness of ICS interventions to mitigate HAP. Thus, identifying existing research gaps informs future research and recommends for best intervention strategies. This review supports making policy regarding environmental issues and helps to achieve the SDG goal of Nepal.

ICS Intervention in Nepal

The history of ICS in Nepal dates back to the early 1950s, By 2014, more than 740,000 ICS had been distributed throughout the country. Additionally, 14,000 metallic ICS (high hills) and 1,500 Institutional ICS (IICS) had been installed. Mud ICS have been distributed in 2,655 Village Development Committees (VDC), 33 municipalities, and 63 districts, and over 8000 promoters and stove masters have been trained ICSs are becoming increasingly popular by the day with the involvement of INGOs including World Wildlife Fund Nepal (WWF-Nepal), International Centre for Integrated Mountain Development (ICIMOD), the Netherlands Development Organization (SNV), and the International Union for Conservation of Nature (IUCN); NGOs including and private-sector entities like Practical Action Nepal and Matribhumi Urja Pvt. Ltd. Depending on the geographical location, climatic condition, and socio-economic indicators in the area of distribution, several programs have distributed a wide variety of ICS. (Hariyo Ban Program, Thapa & Subba, 2015)

Picture 1: Traditional Cooking Stove and Improved Cooking Stove in Nepal

Traditional Cooking Stove (TCS)	**Improved Cooking Stove (ICS)**	**Improved Cooking Stove (ICS) Model**
		
Traditional Cooking Stove Used in Tamankhola Rural Municipality	**Improved Cooking Stove used in Konjyosom Rural Municipality Nepal**	**Improved Cooking Stove Model**

Objective of the review

We conducted a systematic review to assess the Impact of improved cooking stove interventions on the reduction of household air pollution, firewood, and positive health effects in Nepal.

Specific research question

What are the impacts of improved cooking stoves on household air pollution levels especially, particulate matter, and carbon monoxide, compared to traditional cooking stoves in Nepalese households?

Do improved cooking stove intervention programs increase positive health effects for people living in rural parts of Nepal?

Can improved cooking stoves reduce firewood consumption in rural Nepalese households?

Findings provide an in-depth understanding of these interventions are required to achieve the SDG goal (3): Ensure healthy lives and promote well-being for all at all ages, goal (7): Ensure access to affordable, reliable, sustainable, and modern energy for all; and Goal (13): Take urgent action to combat climate change and its impact.

METHODOLOGY

Search Strategy

We included the studies published between 2000 to 2023. Key concepts of the systematic review are ' Improved Cooking Stoves', 'Intervention', 'Impact on Health', 'Household Air Pollution', and 'Nepalese People' we extend our search terms in the following (Table 2).

Inclusion and exclusion criteria

We specify the inclusion and exclusion criteria for the review concerning the study characteristics including population, intervention, comparator, outcomes (PICO), study designs, time frame, publication status, and language (Table 1).

	Keywords		**Search terms**
	Improved Cooking Stoves	OR	"Improved biomass stoves" OR "Efficient cook stoves" OR "Clean cookstoves" OR "Improved stoves"
AND	Intervention	OR	"Air pollution mitigation strategies" OR "Evaluation of stove performance" OR "Monitoring the effectiveness of stove"
AND	Impact on Health	OR	"Positive health outcomes" OR "Health impact assessment" OR "Health improvements"
AND	Household Air Pollution	OR	"Indoor Air Pollution" OR "PM 2.5 and CO level" OR "Particulate matter and carbon monoxide" OR "Impact on the environment" OR "Indoor air quality" OR "Indoor smoke" OR "Household smoke"
AND	Nepalese People	OR	"Nepali Population" OR "People in Nepal" OR "Nepalese families"

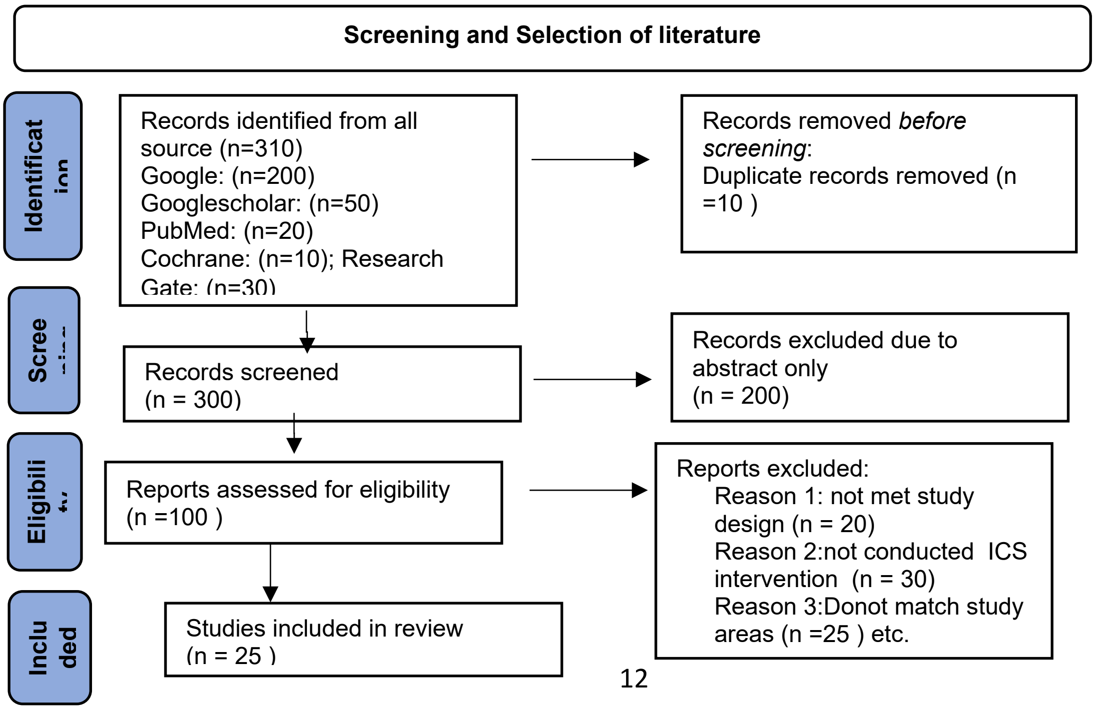
Table 2: Search strategy on key concepts and search terms

PICOS. Framework	
Population	Communities of Nepal receiving improved cooking stove interventions We excluded interventions utilizing LPG, solar, biogas, and charcoal pellets.
Intervention	Improved biomass cooking stoves (ICS) at National and Local levels Government and nongovernmental program
Comparison	Compare the post-intervention values of HAP and emission of pollutants, energy emission, and impact on health with the baseline values, which correspond to traditional cookstove use before and after design
Outcomes	Intermediate outcomes: Energy efficient Longterm: health impact and emission of air pollutants
Study Design	Randomized control trials (RCTs), quasi-experimental designs (natural experiments, before-after studies, cross-sectional)

Time and Duration: We included studies published between January 2000 and June 2023.

Publication Language: Due to resource constraints, this systematic review was conducted exclusively in English. Therefore, it only includes studies published in English.

Figure 1: Screening and selection of article



Selection Process and data collection

The process of article selection will be conducted through three steps: 1) title screening; 2) abstract screening; and 3) full article screening. All extracted articles will be stored in

Mendeley Reference Manager and the duplication were eliminated. two reviewers will independently review all titles and abstracts in the PDF to further identify each study for eligibility against our inclusion and exclusion criteria. After identifying the included titles and abstracts, we downloaded all qualifying studies through Google, Google Scholar, Research Gate PubMed, and Cochrane. Two analysts independently reviewed each qualifying study, extracting all relevant data to ensure that data and outcomes were correctly interpreted and extracted. The two analysts then compared findings to resolve any disagreements or differences in interpretation. For any matters for which the analysts could not reach an agreement, a third analyst reviewed the study to provide input Our systematic review identified 310 potential articles. After duplicates were removed, title screening occurred on 300 studies of which were further screened on abstract then 200 articles were excluded due to abstract only and 100 full texts met the eligibility criteria. A total of 25 studies were found to meet the full inclusion criteria (see Fig. 1 for a flow chart of study selection). Studies were included on the grounds of study type (ICS stove intervention or evaluation of ICS stove intervention studies were included); the study setting (intervention occurring in natural settings); the study country (only studies from Nepal were included and comparison with others countries in the discussion section).

Data synthesis

To synthesize the data from the included studies, we adopted a systematic approach that involved several key steps. First, we performed a comprehensive literature search to identify relevant studies on the impact of improved cooking stoves on household air pollution and health outcomes among Nepalese people. We screened the titles and abstracts of the identified studies for eligibility and then conducted a full-text review of the selected articles. Data extraction was carried out using a standardized form to ensure consistency and accuracy. This form captured information on the study design, study area, study year, comparison group, intervention details, outcomes measured, and key findings. We then assessed the quality of the included studies using established criteria. To synthesize the data focused more on qualitative than quantitative. Qualitatively, we provided a narrative summary of the key findings from each study. This involved identifying and highlighting common themes, patterns, and discrepancies across studies. For instance, many studies consistently reported a reduction in indoor air pollution levels, increased thermal efficiency, and decreased respiratory illness following the introduction of improved cooking stoves. Finalized the themes such as Reduced emission of indoor air pollutants, improved health outcomes, and increased energy efficiency were explored

Based on the synthesized data, we discussed the practical implications of improved cooking stoves on public health in Nepal. Recommendations for policymakers and stakeholders were provided, emphasizing the importance of adopting clean cooking technologies.

RESULTS AND DISCUSSION

After reviewing the selected articles, we noted the basic effects of household air pollution (Environment and Health). Based on these effects, we analyzed the effects of ICS use, specifically on HAP and health, along with thermal efficiency which are described in the tables.

Reported effect of ICS stove intervention on Environment and Health.

We examined the effect of ICS stove interventions which were conducted in Nepal, The majority of authors reported a positive reduction of HAP after the installation of an improved stove. Primarily, the main pollutants measured were carbon monoxide (CO) and particulate matter (PM). The time frames of measuring pollutant concentration were 24 hours measurements, these reductions were not enough to meet WHO air quality recommendations. (Bikram & Thakuri, 2009); ;(Parajuli et al., 2016); (Singh et al., 2012); (Dahal & Parajuli, n.d.). A wide range of health outcomes were also reported across the studies. Self-report measures within studies reported a reduction of respiratory and other illnesses in the intervention group.

We examined the effect of ICS stove interventions which are useful in the reduction of firewood consumption, and help to the conservation of forests as well. (Bikram & Thakuri, 2009; Singh et al., 2012; Johnson et al., 2013; Prasad et al., 2014; Gawande et al., 2013).

Table 3 shows that three articles conducted in Nepal highlighted the combined positive outcomes of ICS stoves: increased energy efficiency, reduced HAP, and improved health of Nepalese people. Furthermore, Table 4 shows that improved cookstoves help to reduce firewood consumption, which benefits environmental conservation efforts. Similarly, Table 5 reveals that improved cookstoves contribute to a reduction in indoor air pollutants, enhancing indoor air quality.

Firstly, Reviewed the selected articles and noted the main impact of ICS use as compared to TCS. We generated three thematic areas; specifically, the impact of ICS on the reduction of HAP, increase the thermal efficiency, and improvement of the health status. Based on these three areas, We discussed the impact of ICS use in Nepal and then compared it with South Asia, and found similar findings.

Situation of Household Air Pollution in Nepal

A study conducted in Nepal shows that 24-hour average $PM_{2.5}$ concentrations were found to be more than the WHO guideline of 25 $\mu g/m^3$ and the national ambient air quality standard (NAAQS) of Nepal (40 $\mu g/m^3$). (Adhikari et al., 2020)

The study was conducted in the traditional village of Chaurikharka in the Khumbu Valley (Nepalese Himalayas) and shows similar findings, $M_{2.5}$ and PM_{10} average concentrations were 35 ± 24 $\mu g\ m^{-3}$ (range: 1–648 $\mu g\ m^{-3}$) and 113 ± 64 $\mu g\ m^{-3}$ (range: 1 $\mu g\ m^{-3}$ to 1945 $\mu g\ m^{-3}$), respectively (Pratali et al., 2019)

A study found that Indoor PM2.5 levels for both wood and LPG fuel homes exceeded the WHO's recommended 24-hour limit of 25.0 μg/m3, but the exceedance was most pronounced for wood fuel homes. (Johnston et al., 2020), similarly, a study shows that $PM_{2.5}$ measures, compared with electric stoves, use of LPG, kerosene, and biomass stoves were associated with increased indoor $PM_{2.5}$ concentrations of 65% (95% CI:

38e95%), 146% (103e200%), and 733% (589 e907%), respectively (Pokhrel et al., 2015).

Table 3: Impact of clean cooking interventions on Environment and Health

Study, Author, Year, Country	Study Design	Interventions	Outcomes		
			Energy efficient	Emission of indoor air pollutants,	Impact on Health
(Bikram & Thakuri, 2009) Northern part of central Nepal	Program Evaluation (TCS and ICS stoves)	Installation of Improved Cooking Stove	The average firewood saving per day is 3.15 kg per household (roughly1150kg/year)	The 24-hour average CO level is 9.39 ppm in households with traditional stoves compared to 2.26 ppm that is, 76% less in households with smokehoods.	The occurrence of respiratory illnesses (e.g., cough, phlegm, and wheezing symptoms) is significantly different among the women and children of the intervention and control groups.
(Parajuli et al., 2016) Palpa Nepal	IAQ measurement of TCS and ICS stoves	Installation of Improved Cooking Stove		The mean CO and $PM_{2.5}$ concentrations for ICS and TCS are 27.11 ppm and 825.4 lg/m^3 (27.11 ± 14.24 ppm and 825.4 ± 730.9 lg/ m^3) with significant correlation ($p < 0.0001$)	The prevalence of key respiratory health symptoms in both women and children is reported lower in ICS users than in TCS users. e.g., coughing, difficulty in breathing, wheezing, and irritation problems are decreasing (65 to 50%, 70% to 55%, 85% to 52%, and 95 to 42% respectively.
(Singh et al., 2012) Western, central, and eastern parts of Nepal	longitudinal, "Before and After" research design	Installation of ICS by Household Energy and Health Project	Users recognized a high reduction of IAP levels in the kitchen (85.3%), less time spent cooking (50%), and reduced wood consumption.	After 1 year of ICS use, the mean values of $PM_{2.5}$ and CO were reduced by 63.2% and 60.0% respectively. $PM_{2.5}$ Concentration was significantly lowered from 2.07 mg/m^3 during (TCS) use to 0.76 mg/m^3 during ICS use. The mean CO concentration was reduced significantly	Episodes of cough, phlegm headaches chest wheezing or whistling, and eye irritation are decreased while using ICS as compared to TCS (55%) to 36.1 % 69.4% to 44.4%, 25.5% to 8.0%, 83.1% Vs 61.0% 75% to 22.2% in mothers.

				from 21.5 ppm to 8.62 ppm.	

Table 4:Impact of improved cook stove reduction firewood consumption

Study, Author, Year, Country	Study Design	Intervention	Outcome: Energy efficient
(Johnson et al., 2013) Nepal	Stove performance testing compared with TCS and ICS	ICS is designed for wood use, constructed of mud bricks, a mixture of clay, cow dung, sugar/ molasses, salt, and rice husks, reinforced with iron support rods, and with chimneys to vent the smoke outside.	The intervention stove demonstrated significant wood savings per standard adult (30%) and per standard adult meal (26%), The Nepal Improved Cooking Stove demonstrated slightly higher fuel savings. Testing through Water Boiling Test (WBT), Controlled Cooking Test (CCT), Kitchen Performance Test (KPT):
(Prasad et al., 2014); Buffer Zone of Chitwan National Park, Nepal	Evaluation of ICS stoves compare with traditional cooking stoves (Before and After) through survey	Installation of ICS stove to be more efficient compared to the traditional cooking stoves.	It has been found that the average firewood consumption by a family was 310.62 kg/month before the application of ICS, which was reduced to 253 kg/month after adopting it.

Table 5: Impact of improved cook stove for reduction of indoor air pollutants

Study, Author, Year, Country	Study Design	Intervention	Outcomes: Emission of indoor air pollutants,
(U. Sharma & Bahadur Darlami, 2016) Tarai, Hilly, and Mountain regions of Nepal	Comparative study of TCS and ICS stoves.	Effectiveness analysis of different kinds of stove use and LPG gas uses for reduction of CO2.	Intervention A, in the Terai region, by the year 2030 a total of 96, 028, 132; 107,125, 603and 128, 426, 683 tCO_{2e} GHG emission reduction can be achieved by using general Mud ICS, Rocket mud stove, and rice husk, Gasifer, stove respectively.

(Prasad et al., 2014); Buffer Zone area of Chitwan National Park, Nepal	Evaluation of ICS stoves compare with traditional cooking stoves (Before and After) through survey	Installation of ICS stove and comparison with traditional cooking stoves.	Before the application of ICS, CO_2 emission from a household was calculated at about 568.43kg/month which was found to decrease to 462.99 kg/month
(Dahal & Parajuli, n.d.) Rasuwa, Province 3, Nepal	Analysis through National Indoor Air Quality Standard (NIAQS) The 24-hour $PM_{2.5}$ average and the average 1hour concentration of CO in both the houses using ICS and TCS	Installation of ICS	Emission from ICS is comparatively lower in terms of CO and $PM_{2.5}$ (9 ppm and 155.26 μg/m^3). As compared to emissions from households with TCS (12 ppm, 385.12 μg/m^3).

Impact on Health by Using Biomass Fuel

A study conducted in Nepal shows that people reported health problems among biomass users, Dsypnoea and wheezing were more common among biomass users compared to those who used non-biomass fuel ($p < 0.001$), with the age-adjusted prevalence of dyspnoea being 17.8% (among female and 12.0% among male biomass fuel users, compared to 7.6% and 2.5% among cleaner fuel users. (Kurmi et al., 2014), this study aligns with a study conducted among 741 participants above 40 years, all were unclean (wood and mixed) fuel users. Participants with more than 40 years of reporting breathlessness were found 16.44 percent who were using fuel wood. Similarly, reporting breathlessness was found in 10.51 percent who used mixed types of fuel, and it was not found in clean fuel users. (NHRC, 2016)

ICS Increased Thermal Efficiency and Decreased the HAP

The study establishes that the mud ICS is an appropriate intervention to reduce $PM_{2.5}$ and CO in rural kitchens in Nepal. After 1 year of ICS use, the mean values of $PM_{2.5}$ and CO were reduced by 63.2% and 60.0% respectively. $PM_{2.5}$ concentration was significantly lowered from 2.07 mg/m^3 (95 % CI: 1.42–2.71) during traditional cookstoves (TCS) use to 0.76 mg/m^3 (95 % CI 0.521–1.00) during ICS use. The mean CO concentration was reduced significantly from 21.5 ppm (95 % CI: 14.5–28.6) to 8.62 ppm (95% CI: 6.18–11.1) Singh et al., 2012a), a similar finding was found in two sequential trials conducted in rural low-lying Nepal. Trial 1 was a cluster-randomized step-wedge trial comparing traditional biomass stoves and improved biomass stoves vented with a chimney. The intervention was a 2-burner biomass stove with a chimney to vent smoke to the outside. Measuring the mean kitchen-based 1-day average PM2.5 was measurements in households lowering from 1380 (95% CI=1336, 1425) lg/m3 during traditional stoves to 936 (95% CI=895, 978) lg/m3 during using improved biomass stove. In trial 2, the improved biomass stove had a similar PM2.5 concentration to those in trial 1 at 885 (95% CI=810, 959) lg/m3 (Katz et al., n.d.)

A study conducted in the rural village Kopiwatta, Srilanka to monitor IAO levels found that lowering PM 2.5 (2.08.0 ±140.2) μg/m^3 during traditional cook stove without chimney from (76.0 ±37.7) μg/m^3, during Anagi improved cooking stoves with chimney. Study shows that Anagi stoves are useful for lowering the CO concentration (4.72 ±3.26 to 0.9 ±1,08) mg/m^3. (RTI,2001), similarly Quantitative monitoring and evaluation of the impacts of improved stoves have been performed in Mexico. Grupo Interdisciplinario de Tecnología Rural Apropiada (GIRA) has recently disseminated 4,000 improved Patsari cookstoves, Mexico found that reductions in PM2.5 and CO concentrations from paired comparisons (ICS with TCS) before and after installation of the Patsari in 33 homes from (1.02 to 0.34) mg/m^3 and (8.88 to 3.02) ppm)respectively. The overall average PM2.5 and CO reductions observed as a result of installing the Patsari were 66 % ($p < 0.001$) and 67 % ($p < 0.001$) respectively (Masera et al., n.d.)

A study shows that ICS adoption in two villages of Nepal saving per meal comes out to 0.531 kilograms per meal and more than 30 kilograms per month (Gawande et al., 2013) which is similar to a study conducted in Nepal found that the average firewood consumption by a family was 310.62 kg/month before the application of ICS, which was reduced to 253 kg/month after adopting it. (Prasad et al., 2014) , similarly, the research conducted in Samagaun which lies in the mountain region of Nepal concluded that the total firewood consumption in the area is 7668.6 kg per year with 106.42 kg per capita per year. The per capita firewood consumption for TCS users was 1.3 times more in comparison to ICS users (Suwal, 2016).

ICS Improved the Health Status

In a study conducted northern part of central Nepal, the occurrence of respiratory illnesses (e.g., cough, phlegm, and wheezing symptoms) is significantly different among the women and children of the intervention and control groups. (Bikram & Thakuri, 2009), similarly, a cross-sectional survey conducted in Rasuwa district, Nepal shows that ALRI could be substantially reduced if these stoves are replaced by improved ones in rural areas of Nepal After adjusting for the factors like mother's group status, ethnic group, age of children, mother's group membership status and father's occupation, use of traditional/open type of cooking stove was found to be highly associated with ALRI. (S. R. Sharma et al., 2015)

A study was conducted in selected rural locations of Ratnanagar municipality, Chitwan found that considering the background PM2.5 concentrations, there could be 37 (24–50), 91 (57–126), and 4 (3–5) cases of mortality due to COPD, IHD, and ALRI respectively However, the difference in the number of COPD, IHD, and ALRI cases between village and background air pollution is 3, 3, and 0, respectively, which also represents the village-level household contribution to ambient air pollution. This result indicates that most of the COPD, IHD, and ALRI cases could be attributed to background pollution. (Prasad et al., 2014)

In a study conducted in the southern part of Nepal, the intervention showed similar findings with a 13% decline in the incidence of ALRI but the strength of evidence was weak (0·87, 95% CI 0·67–1·13). There were statistically significant reductions in persistent cough (0·91, 0·85–

0·97), wheeze (0·87, 0·78–0·97) and burn injury (0·68, 0·48–0·95). (Katz et al., n.d.) A cross-sectional community-based comparative study was carried out in Bangladesh to assess COPD and other respiratory illnesses among the women who used ICS. For comparison, the women who used TCS found that TCS users showed that COPD (23.6%) and other respiratory illnesses (49.5%) were significantly (p=.001 and p=0.014 respectively) higher than those of the ICS users. Logistic regression analysis revealed that biomass fuel had the strongest ability (3.8 times) to predict COPD followed by the ability (1.8 times) of TCS use. (Ahmad et al., 2020)

LIMITATIONS OF THE REVIEW AND FUTURE DIRECTION

Many studies included in the review did not follow participants for extended periods. Long-term health outcomes and sustained environmental impacts of ICS use remain under-explored. Differences in the methods used to measure pollutants and health outcomes across studies can lead to inconsistencies. For instance, the duration and frequency of air quality measurements were not uniform, and self-reported health outcomes may be subject to bias. There is a potential for publication bias, as studies reporting significant positive effects are more likely to be published than those with null or negative results. This review lacks a meta-analysis, which could affect the robustness of the findings. Further study should include a meta-analysis which helps to synthesize evidence from diverse studies quantitatively.

Research should consider integrated approaches that combine ICS interventions, focusing not only on the stove itself but also on the analysis of kitchen ventilation. This comprehensive approach can significantly impact the outcomes of the intervention on both the environment and health. This review focused primarily on studies conducted in Nepal. This limits the generalizability of the findings to other regions with different cultural, environmental, and socioeconomic contexts. Expanding research to include diverse geographic regions will help to understand how regional differences affect the outcomes of ICS interventions.

CONCLUSION

Household air pollution is an important global health problem with significant morbidity and mortality. Most of the articles show that the 24-hour average $PM_{2.5}$ and CO concentration were found to be more than the WHO guideline of 10 μg/m^3 and 35 ppm in all ICS interventions however ICS helps to drastically reduce the $PM_{2.5}$ and CO concentration as compared with TCS. Review articles also show that reducing household air pollution affects ventilation and chimneys more than types of biomass stoves. Exposure to household-level air pollution due to biomass fuel burning is associated with negative health outcomes. Common health effects are related to cardiovascular and respiratory diseases lung cancer, cataracts, and adverse pregnancy outcomes. These health effects were reduced through biomass fuel burning and improved cooking stoves. Fifty-eight percent of the population lives in households that use solid fuels for cooking whereas 81% in rural areas of Nepal. Wood is the most common solid fuel, in 49% of households which is used more frequently in rural areas (72%) than urban areas (37%).

Therefore, this study recommends that efficiently burning stoves should be designed technically with locally available sources which makes them affordable and culturally acceptable. ICS helps to reduce firewood consumption ultimately lowering the adverse effects on the environment and health of Nepalese people. Thus, this review identifies existing research gaps informing future research and recommending the best intervention activities at the household level. Furthermore, this study recommends that efficiently burning stoves should be designed technically, using locally available sources which makes affordable and culturally acceptable ICS programs. This review also supports making policies regarding environmental issues and developing plans to achieve the SDG goal 2030 of for Nepal.

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