Carbon Monoxide Emissions and Human Exposure Assessment of Different Cookstoves in Kaski, Nepal

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Abstract

Commonly, women and children are exposed to very high level of criteria pollutants daily over many years. The study aimed to compare the Carbon monoxide (CO) emissions in between traditional, improved and LPG Stoves, and to determine the human exposure level to CO during cooking period. This research was conductedamong 21 households in Kaski, Nepal, selected from stratified random sampling.Data were collected by deployment of ToxiRAE Pro and analyzed by Microsoft Excel. Results showed thatTCS has 5 times and 6 times higher CO emissions, 7 times and 20 times higher exposure level than ICS and LPGS respectively. In addition, ICS has less than 1.5 times higher emissions and almost 3 times higher exposure level than LPGS. Consequently, the kitchen room with TCS was the dirtiest in terms of CO emissions, time consumption, and exposure level. LPG stoves could be used to improve indoor air quality, health conditions and reduce time spending in kitchen. ICS could also be best option in the sense of cost effectiveness for installation and operation in rural areas of developing countries.

Keywords: Indoor air pollution, CO emissions, cookstove, exposure

1. Introduction

The toxic contaminants that we encounter in our homes, schools and workplaces in daily lives are refers as an indoor air pollution. Cooking fuels such as biomass, kerosene oil and liquefied petroleum gas (LPG) contain a large number of pollutants named particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2) and formaldehyde (Ezzati & Kammen, 2002). Indoor air pollution (IAP) in developing world from biomass smoke is considered to be a significant source of public health hazard.The traditional domestic practice of cooking in primitive stoves with low-grade fuels and in badly ventilated kitchens can have serious implications for the health, particularly to the women and children(Joshi, 2006)&(Saksena, et al., 2002).

CO is one of the component of 'criteria pollutants' recommended by WHO. It is a colorless, tasteless, odorless, nonirritating, and poisonous gas emitted from incomplete combustion of carbonaceous material used as fuels for transportation, cooking, and heating(Fierro, O'Rourke, & Burgess, 2001). A health effect is determined not just by the pollution level, but also by the time people spend breathing polluted air, i.e. the exposure level.Compared with concentration, exposure is a more accurate measure of human contact with pollution (Zou et al., 2009).

Nepal is a country of village where more than 80% live in villages and among them, 75% population are using the unprocessed biomass. The housing structure is very vulnerable for IAP because 70% households have wooden and mud bonded house with poor ventilation(Kim, et al., 2015). In Nepal, biomass is a dominant source of energy(about 87%), whereas 89.1% of total energy is consumed in the residential sector for cooking and heating purpose (Lohani, 2011).

In developing countries, poor women and young children are commonly exposed to very high levels of pollution daily over many years. Though there have been no large-scale statistically representative surveys about the household CO emissions from different cooking fuels (especially biomass vs LPG fuel),therefore it is very difficult to find literatures about real image of CO emissions and exposure level during cooking period. The testing protocols and experimental setup that simulate cooking practices under the controlled and replicable conditions of laboratory may not be realistic of the real world application of a stove.Hence, this study was conducted to compare the CO emissions in between traditional cook stove (TCS), improved cook stove (ICS) and LPG stove and to determine the level of human exposure to CO during cooking period inside the kitchen of people in the study area.

2. Methodology

2.1 Study Area Location and Sampling techniques

The study was conducted in Kaski District at Sarangkot VDC of Nepal. This area was chosen purposively because there is variation in cooking fuels and stoves, heterogeneity in socio-economic, and geographical structure.Stratified random sampling method was applied to meet the objectives in this research. Three different strata were made according to the type of cooking stoves and did not include those households who have been used more than one stoves for a particular meal. A representative sampling of 21 households (7 households of each TCS, ICS, and LPG Stove) were surveyed in the study areaduring April to May 2016 to obtain the required data.

2.2 Data Collection and Analysis

The study was based mainly upon primary data so data were obtained by device setup and household questionnaire survey. The CO detector named "ToxiRAE Pro" was used for the quantitative measurement of CO emissions from kitchen during cooking period. Ambient CO level on same time was also measured to obtain exact CO emission from cooking fuels.Data had been downloaded from the devices with the help of "ProRAE Studio II" software.Various literatures and dissertations regarding the CO emissions and exposure related to IAP were collected and reviewed from internet, books, journals etc. as a secondary source to facilitate the research.

The collected data were entered intoMicrosoft Excel 2013. All the necessary statistical tools like tables, graphs, charts, mean values were formulated by that program. The one minute average value of CO emission was recorded by the device and analysis had been done on the basis of that average value. Actual COemissions from stoves had been calculated by subtraction of ambient CO level from CO level inside the kitchen.

Actual CO emissions = CO level inside kitchen – CO level in ambient air.

CO Concentration of kitchen room had been calculated through;

$$\text{CO Concentration} = \frac{\text{CO Emissions}}{\text{Volume of room}};$$ where unit of CO concentration is mg/m^3.

Exposure Level = Concentration of kitchen × Total time that they spend

i.e. $E = C \times T$; unit of exposure level is ppm-h (Ott, 1982).

3. Results

The average time taken for cooking in 3 different cookstoves has been presented below.

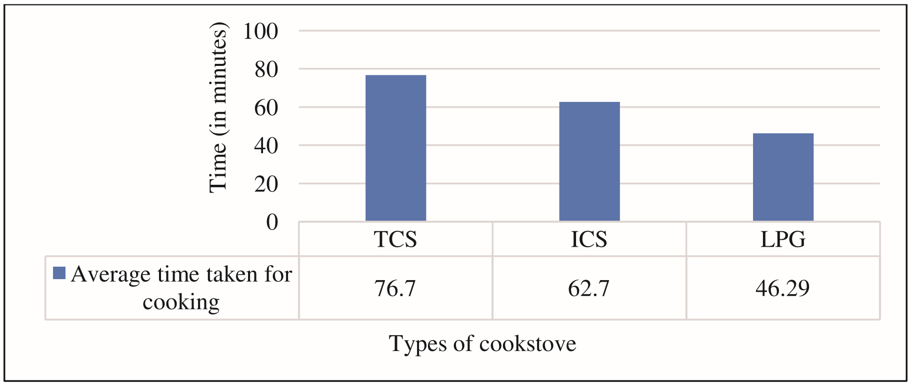

Figure 1. Average time consumption for cooking

In figure 1, it can be clearly seen that people spent maximum time for cooking in TCS with the value of 76.7 minutes while they spent minimum time (i.e. 46.29 minutes)in LPG stove.In ICS, they spent 62.7 minutes in average for making their meal.

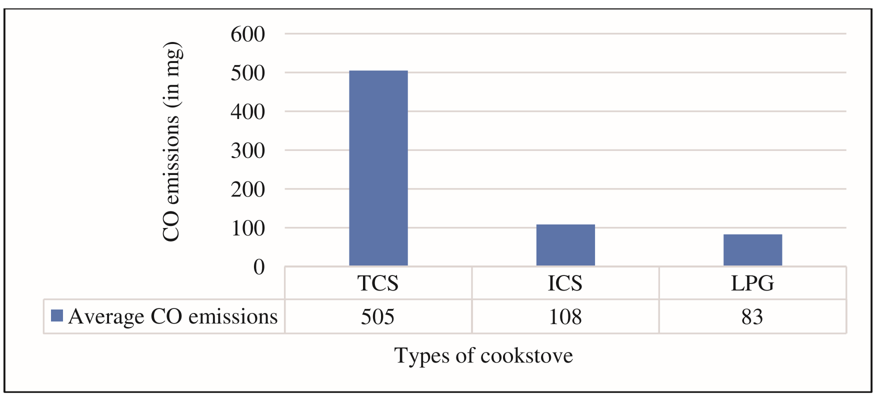

Figure 2. Average CO emissions

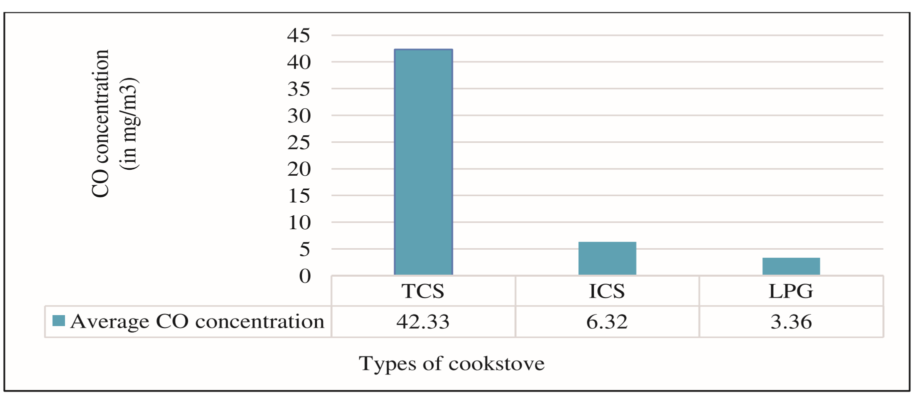

Figure 3. Average CO concentration of kitchen

Among three different types of cookstove, TCS released more CO than others. From Figure 2, average CO emissions from TCS (505 mg) was almost 5 times higher in compared to ICS (108 mg) and almost 6 times higher than LPGS (83 mg). Emissions from ICS was less than 1.5 times higher in compared to LPGS.

Figure 3 shows the graphical presentation of average CO concentration among compared cookstoves.As per emissions pattern, it is obvious that kitchen room of having TCS has maximum CO concentration than that the kitchen of having other stoves. Moreover, kitchens with TCS have around 6 times higher CO concentration than that of kitchens with ICS and around 13 times higher concentration than that of kitchens with LPGS. The difference among kitchens with ICS and LPGS was not really great, kitchens with ICS have almost 2 times greater CO concentration in compared to kitchens with LPGS.

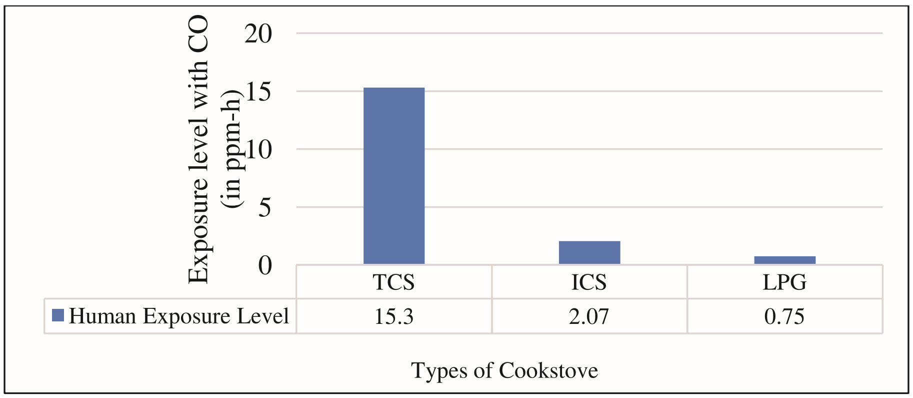

Figure 4. Average exposure level with CO

In Figure 4, level of human exposure has been calculated with the help of CO emissions from cookstove, size of room and total time they spent inside the kitchen room. From the previous results, it is obvious that the human exposure level with CO is much higher in kitchen with TCS in comparison with ICS and LPGS. Average exposure level of peoples in the kitchen of having TCS was 15.3ppm-h which is almost 7 times greater than kitchen of having ICS (2.07ppm-h) and almost 20 times greater than the kitchen of having LPGS (0.75ppm-h). Moreover, average exposure of people in the kitchen of having ICS was approximately 3 times greater than kitchen of having LPGS.

4. Discussion

Carbon monoxide monitoring will remain a useful tool in qualitative ranking of households in terms of emission levels (Ezzati et al. 2000).Most of the researches are based upon the comparisons in between TCS and ICS, therefore it is very strenuous to find researches about CO emissions comparison in between LPG stove and biomass fuel stove during specific cooking time period. ICS has improved fuel efficiency and lower pollutant emissions compared with the traditional 3-stone fire (Jetter & Kariher, 2009). Even though the emission from ICS to the atmosphere is not changed. An improved cookstoves can reduce CO from burning firewood by 24 % –70 % and also LPG stoves emit 50 times less pollutants than biomass burning stoves (GIZ, 2014).

The use of improved biomass cookstoves significantly reduces the concentrations of pollutants in the kitchen and consequently reduces the exposures and health risks (Kumari et al. 2014). Primary cooks in households without chimneys were exposed to substantially higher levels of HAP than those in households with chimneys, emissions from solid fuel is higher than from gas fuel was found by Chartier et al. (2016).Combustion of biomass fuel soared the level of domestic indoor air quality which exceed WHO standards and are in the detrimental range for human health. (Bartington, et al., 2016)

5. Conclusion

The use of biomass fuels for cooking was the largest source of indoor air pollution. TCS emits 5 times higher CO than ICS and 6 times higher CO than LPG stove, while ICS emits less than 1.5 times higher CO in comparison to LPGS. The study showed that, peoples were spending about 1 hour more time in kitchen per day of having TCS to make their meal in comparison of LPG stove. ICS can reduces half an hour time per day in kitchen during cooking than that of TCS.Level of human exposure in kitchen of having TCS was far greater than LPGS and ICS. Level of exposure in TCS was 20 times higher than in LPGS and 7 times higher than in ICS, whereas kitchen of having ICS has approximately 3 times higher exposure level than having LPGS.

Taking everything into consideration, the kitchen room with traditional cookstove is the dirtiest in terms of CO emissions, time consumption, and exposure level while LPG cookstove is finest form of cooking fuel among three analyzed type of stoves.

LPG stoves could be used to improve indoor air quality, health conditions and reduce time spending in kitchen. To reduce IAP and enhance health quality, improved cookstoves could also be best option in the sense of cost effectiveness for installation and operation in rural areas of developing countries.

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