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CARBON MONOXIDE AND NITROGEN OXIDE EMISSIONS FROM TRADITONAL AND IMPROVED BIOMASS COOK STOVES USED IN INDIA

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ABSTRACT. Cooking is central to our lives. Half of the world's population rely on the unprocessed solid fuels, such as dung cakes, wood, crop waste or coal for cooking. In developing countries like India up to 90% of rural households depends on the solid bio fuels for cooking. Burning bio fuels produces large amount of smoke in the confined space of house, resulting in high exposure. Due to customary role of woman in cooking, she is exposed more. Unprocessed solid biomass fuels are used by the poor urban and rural folk for cooking and heating. According to 2001 census, 78% population of India depends on dung cakes, wood, crop residues for household energy and 3% use coal. The traditional stoves used for cooking are not energy efficient and kitchens are usually unventilated or poorly ventilated, in such condition the fuels are not burnt completely, this results in release of complex mixture of health damaging air pollutants like carbon monoxide and nitrogen oxide which are also the main source of indoor air pollution. There has been much effort in the past in improving the stoves that burn the wood or the charcoal. This paper evaluates and compares the extent to which the pollutants like carbon-monoxide and nitrogen oxides are generated when the biomass fuels, that is, dung cakes and wood are burnt in the traditional stove (U-shaped) as compared to the improved stove (Priyagini) which are commonly used in India. The efficiency of the traditional stove is 12% and that of the improved stove is 23% for the wood as the fuel source.

Key words: Dung cakes, Wood, Traditional stove, Improved stove, Carbon monoxide, Nitrogen oxides

1. INTRODUCTION

The use of biomass fuels like wood, dung cakes and crop residues is widespread in rural India. When used in simple cooking stoves, these fuels emit substantial amounts of toxic pollutants. These pollutants include respirable particles, carbon monoxide, oxides of nitrogen and sulfur, benzene, formaldehyde, 1,3-butadiene, and poly-aromatic compounds, such as bozo(a)pyrene [1]. In households with limited ventilation (as is common in many developing countries) exposures experienced by household members, particularly women and young children who spend a large proportion of their time indoors, have been measured to be many times higher than World Health Organization guidelines and national standards. According to the 61st round of the National Sample Survey conducted in 2004-05, 84% of rural households rely on biomass as their primary cooking fuel [2]. Traditional fuels, as presently used, have inherent disadvantage. Collection is arduous and time-consuming, combustion is difficult to control and cooking methods capture only a fraction of the fuel's available energy. In India, the most commonly used stove for cooking is the traditional stove called 'chulah'. While primarily designed for fuel wood, the same chulah has been adapted to burn crop residue and dung cakes. Households often use more than one type of stove and fuel. A special cooking device called Hara is also used in some of the northern states for milk simmering, making cattle feed and water heating in winter season. The main problems associated with these cooking devices are their inability to vent smoke out of a room, which causes significant levels of indoor air pollution [3, 4]. The use of traditional fuels may have serious consequences for human health. In spite of the inherent disadvantages associated with traditional fuels/stoves, majority of the rural population use them even in areas with access to cleaner fuels.

CO and NO_X are often considered to be most damaging air pollutants from health point of view [5, 6]. Current estimates indicate that combustion of fossil fuels and biomass fuels contributes about 44% of the total global CO budget [7]. CO is considered an indirect greenhouse gas due to its close coupling to atmospheric methane (CH_4), a strong greenhouse gas [8, 9]. However, the uncertainty of the current estimates is large, partly due to the lack of an accurate database of CO emission factors. A significant fraction of all biomass combustion occurs in enclosed or semi-enclosed spaces in inefficient cooking devices mainly in developing countries [10, 11]. Such small-scale devices are expected to have different emission factors compared to the open, large-scale combustion. Unfortunately, few measurements have been made to determine emission factors for these devices in developing countries. Thus, it is necessary to conduct measurements of emission factors for a range of fuels and combustion devices. The present paper reports the results of a study done to find out the emission of Carbon Monoxide (CO) and Nitrogen Oxides ($NO_{X)}$ emissions from the traditional and improved biomass cook stoves used in India. The cook stove-generated CO and NO_X emissions were then compared with the health-based CO and NO_X standards and guidelines.

2. METHODOLOGY

The experimental study was carried out at Indian Institute of Technology, Delhi. Water Boiling Test (WBT) was done systematically for a range of fuel/stove combinations. Eight fuel/stove combinations were tested in a simulated kitchen. Since it is known that emissions from most solid fuels can vary during the burning process, integrated sampling is needed to cover a whole burn cycle from fire start to fire extinction in order to obtain emission data that can represent the real burning situation [11, 12] .In addition, as with many household appliances, it is necessary to choose a particular use cycle for fair comparison among different stoves. In the present study, we used the 'water boiling test' procedure developed as a standard international method [13]. In WBT a pot containing known amount of water was placed on a cook stove during each experiment. The initial and final water temperature and the amount of water evaporated were measured for each burn cycle. Hence, the energy received by the pot can be determined. This procedure has an added advantage of enabling the simultaneous measurement of emissions and stove efficiencies, thus facilitating future calculations of the impact of changes in one or the other. The burn cycles ranged from 70 to 80 min for all other types of fuel/stove combinations. A typical sampling configuration from upstream to down-stream included a sampling probe, a filter holder, a pump and an instrument for CO and NO_X measurement Testo 350 'XL'. The stoves were placed under a hood built for the study, and the probe was placed inside the hood exhaust pipe. The indoor CO and NO_X was measured with a battery operated Testo 350 'XL' regularly at an interval of one minute during the complete burn cycle. Even after extinguishing the fire the concentration was further monitored until its concentration reduced to the background values. Three successful tests with complete burn cycles were conducted for both the types of stoves.

3. RESULTS AND DISCUSSION

Table1 shows the average values of CO and NO_X emitted from different fuel/ stove combinations tested in the study. As per National standards set by Central Pollution Control Board (CPCB) the safer limit for CO and NO_X are 2 mg/m^3 and 0.03 mg/ m^3 for 8 hours and 24 hours respectively. From table 1, we can see that these limits are many times higher then the safer limits prescribed by CPCB. The efficiency of the traditional stove is 12% and that of the improved stove is 23% for the wood as the fuel source. The fuels clearly followed the energy ladder as far as emissions are concerned.

Table [1] CO and NO_X emission from the traditional stove (U-shaped) and improved stove (Priyagini) with dung cake and wood as the fuel during the Water Boiling Test

S.No.	Fuel/Stove combinations	NO_X (ppm)	CO (ppm)
1	Dung cake/ Traditional stove	0.080	560

2	Dung cake/ Improved stove	0.013	189
3	Wood/ Traditional stove	0.018	155
4	Wood/ Improved stove	0.010	116

4. EMISSION CONCENTRATIONS AND ENERGY LADDER

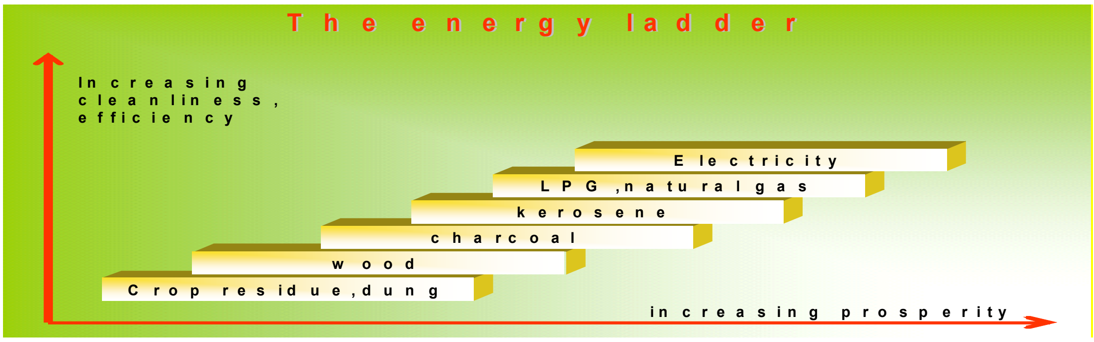

Figure [1] The energy ladder: Linkage between household energy and development

The results shown in Table 1, in general, support a typical household energy ladder concept shown in Figure 1. Cleanliness, energy efficiency, and capital cost increase along the energy ladder in the following order starting from the lowest: dung, crop residue, wood, kerosene, gas and electricity [15, 16]. When using the estimated CO and NO_X concentrations shown in Table 1 as an indicator of fuel cleanliness, our results are in general agreement with the energy ladder concept. In an earlier study, Kandpal et al. (1994) tested four types of biomass fuels: animal dung cake, crop residue (mustard stalk), fuel wood (Acacia) and a mixture of fuel wood and dung cake[17] .These fuels were combusted in a traditional U-shaped cook stove (without flue, hood, or other venting devices) and an improved mud cook stove (with flue). Regardless of which stove was used, the CO concentrations measured in the kitchen air was the highest during burning dung cake, followed by the dung-wood mixture, crop residue, and fuel wood. This trend across the tested biomass fuels is consistent with that shown in Table 1 and also agrees with the energy ladder concept.

5. RECOMMENDATIONS FOR THE EXPOSURE REDUCTION

It is obvious that using LPG or other gas fuels for cooking would result in CO and NO_X levels far below the health-based standards and guidelines. Unfortunately, substitution of biomass fuels with LPG and other gases is not very practical in rural areas in developing countries because cleaner fuel supplies are expensive and often unreliable. In the present situation it seems that complete switching to cleaner fuels like LPG, biogas and electricity is difficult to achieve in near future keeping in view the economic, technical, social and traditional constraints. The demand of biomass fuels may not disappear as fast as may be predicted on a pure fuel transition approach. Our estimates indicate switching from biomass fuels like dung cakes and wood to kerosene would lower the CO emission drastically. Similarly NO_X emissions can also be reduced. If this switch is still not possible for some parts of developing countries, our analysis indicates that even switching from one type or one species of biomass to another one could result in a significant reduction of CO emission. For example, switching from dung to fuel wood would lower the emission by about 2.5 times. And the best option for CO and NO_X reduction is to encourage the use of improved cook stoves having chimneys. By doing so, only a fraction of CO and other pollutants emitted from fuel combustion will be directly released into the kitchen. For example, the CO concentrations measured in the simulated kitchen when an improved stove with a chimney was being used were less than 50% of those measured when a traditional no-chimney stove was being used. Although the emissions to the atmosphere was not changed, use of chimneys can substantially reduce the pollutant concentrations in the kitchen and consequently reduce the exposures and health risks [17]

6. CONCLUSION

The use of solid fuels for cooking and heating is the largest source of indoor air pollution. From the study done we can conclude that the dung cakes used in the traditional stove is the dirtiest fuel in terms of CO and NO_X emissions while improved stove with wood gives the least emissions.

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