Laboratory based assessment of portable multi arm sampler for *in-situ* aerosol emission measurement from residential cooking device

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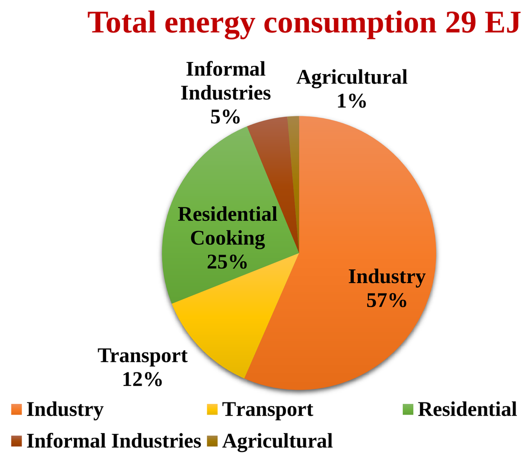
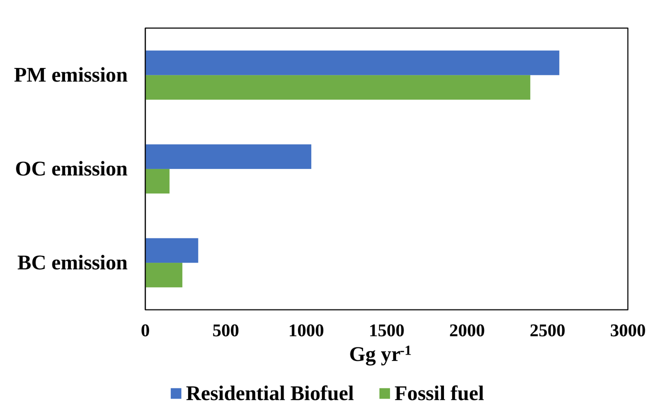
INTRODUCTION

- Emission estimation based on laboratory studies have showed underestimation and are considered to be non-representative of the real world condition data[2].Several simulated studies of biomass burning [1,4] have been performed in the laboratories.
- However, this has been stated as one of the reasons for discrepancy by a factor of 2-4 between climate model simulated and satellite retrieved absorbing aerosol optical depth.
- Hence, there is a need for re-assessment of the emission values from residential cooking devices to fill these gaps and so emission measurement on-field is indispensable to better characterize and understand these sources of emission specially in developing countries.
- With this background the present study was carried out to primarily evaluate a portable multi-arm sampler which will be used in the future studies to characterize the biomass fuel emissions *in the field condition*.
- Our goal in this work was to account for the limitations in field based measurements and overcome the challenges that exist in performing and accessing emissions from on-field cooking fires in rural kitchens in India.

Residential Solid Bio-fuel burning in India



Energy use estimates for India for the base year 2015

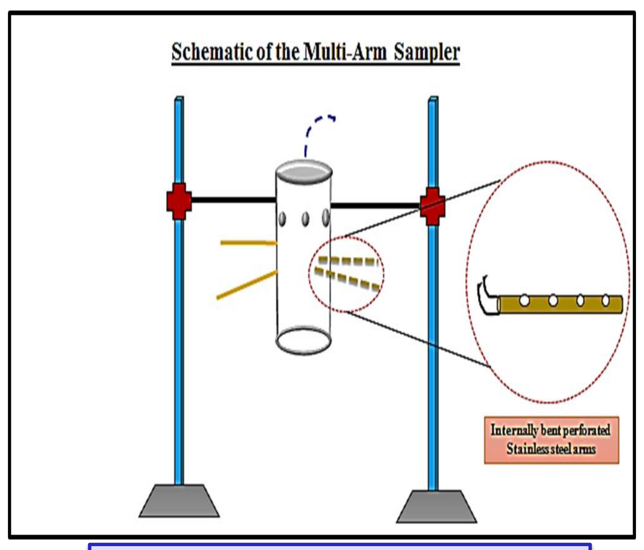


Comparative Emission Estimates from fossil fuel and Residential biofuel aerosol emission for the year 2015

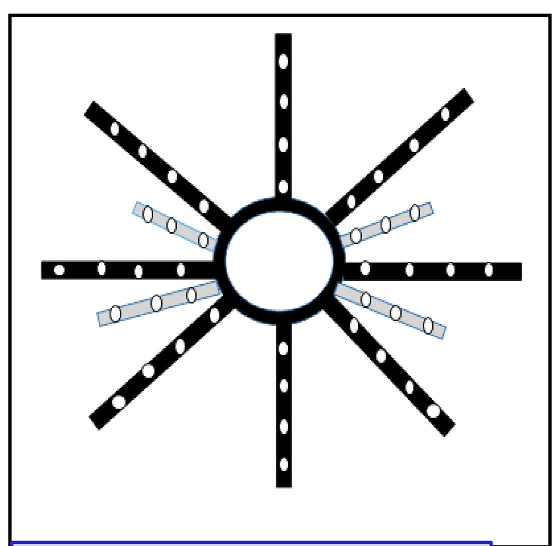
Source: Pandey et al., 2015 ; Sadavarte et al., 2014

Multi-arm Smoke Collecting Device

- 12 sampling arms arranged radially in two (upper & lower levels) each with a length of 50 cm(1 m across)
- All the sampling arms are connected to a middle hollow stainless steel cylinder suspended on top of the cook stove to collect the steady emission.
- Each of the arms has four holes equidistantly arranged.
- A 12mm outer diameter conducting tube is located on the top of the cylindrical part to carry the smoke out and is also smoothly bent. The entire system is supported by two stands of 2 meters height.



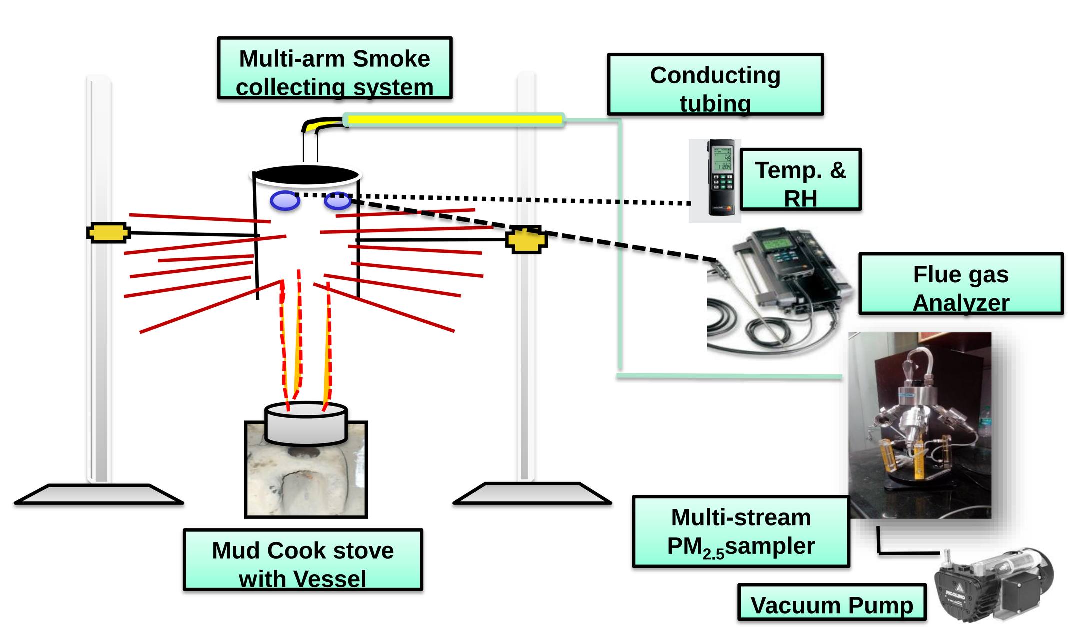
Lateral section view



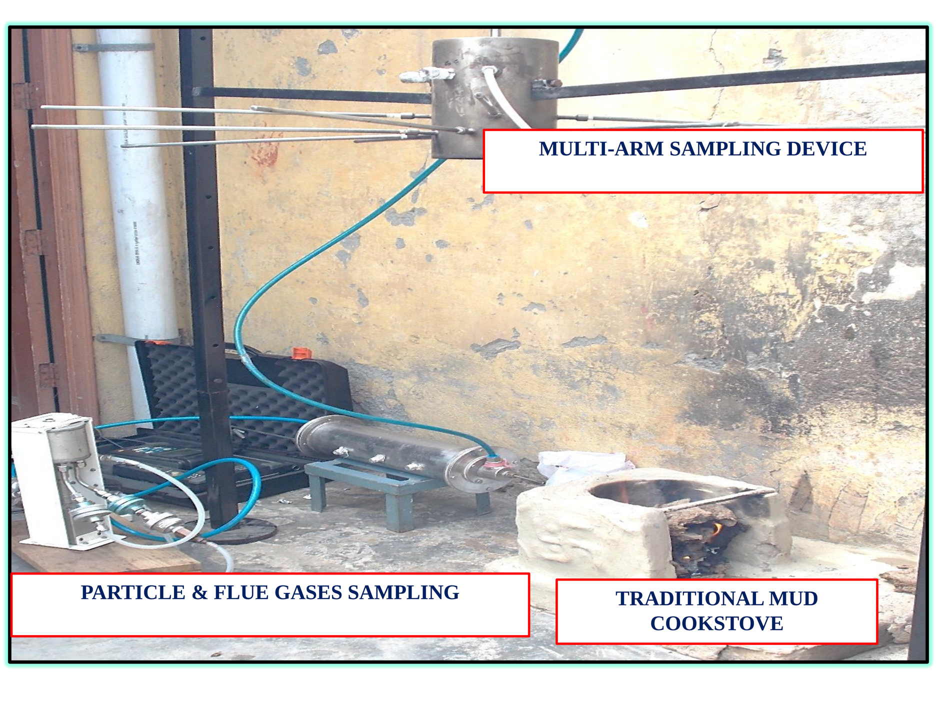
Top-view

Material and Methods

Experimental Set-up

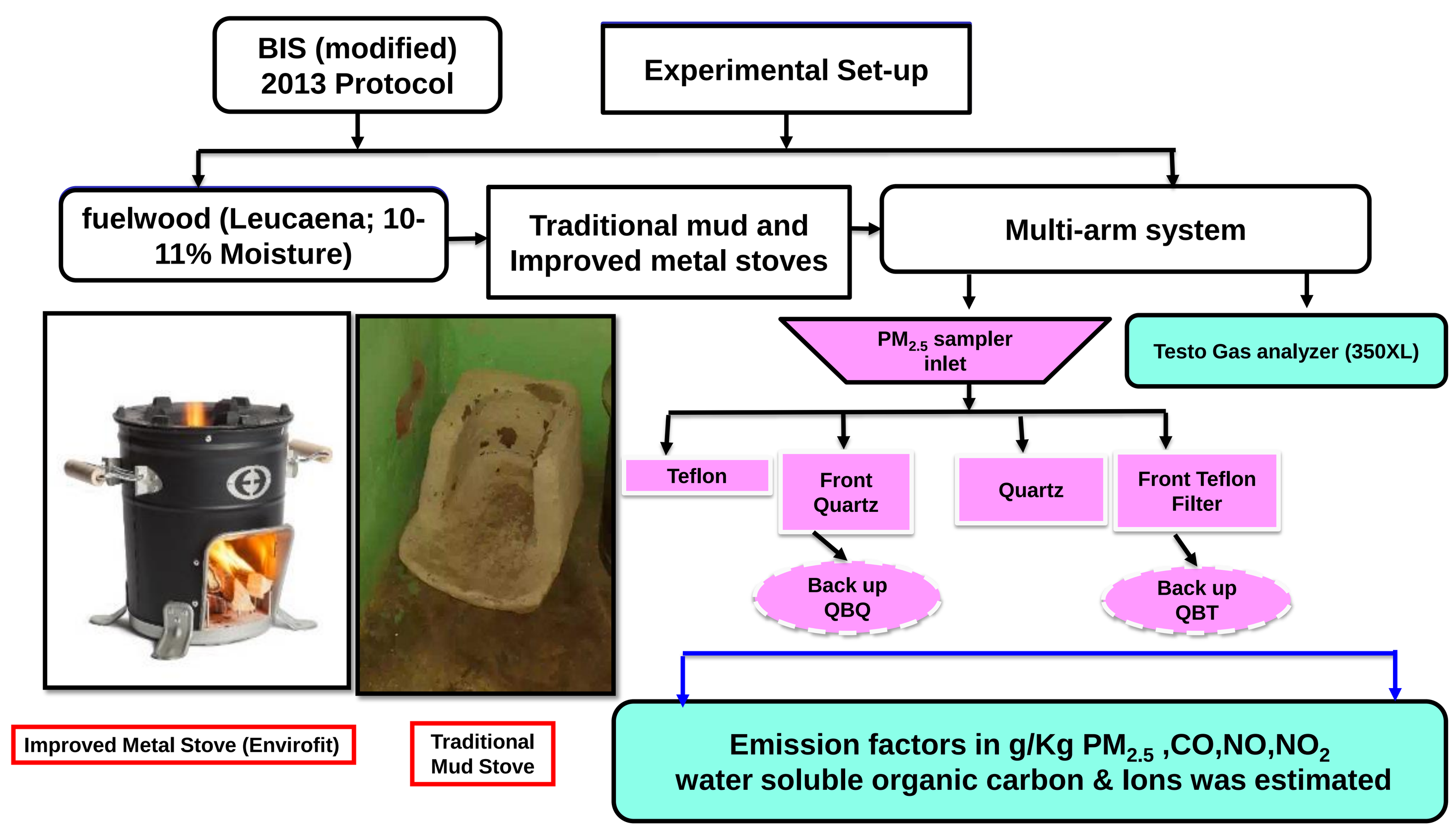


Laboratory sampling Set-Up



On-field Sampling Set Up

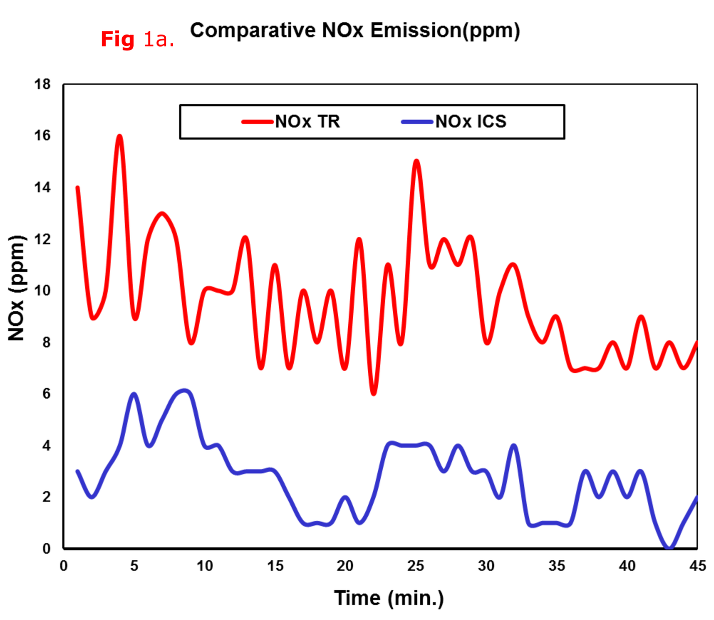
Schematic of Measurement Design

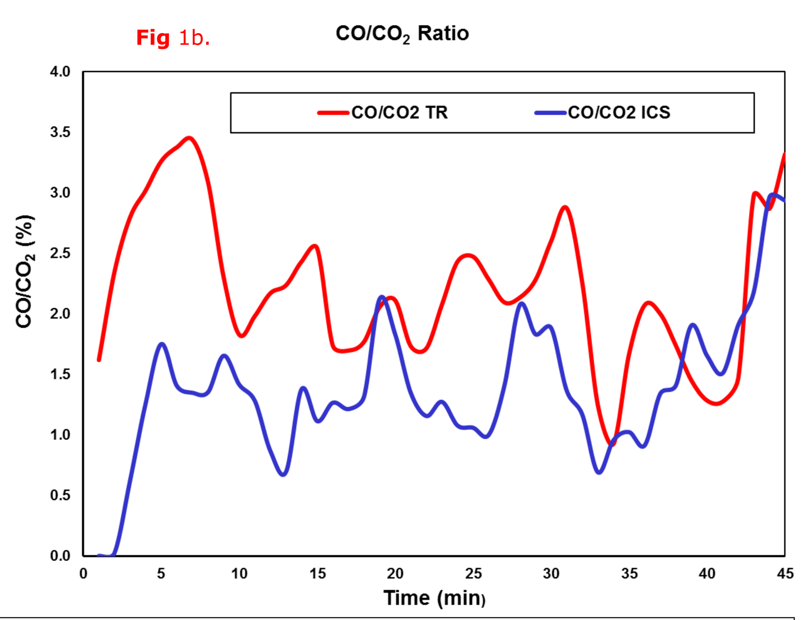


Methodology

- The $PM_{2.5}$ mass was collected in two types of filers Teflon(47mm) and Quartz fiber filter(47mm) respectively using a multi-stream cyclone separator.
- Flue gases were measured with the Testo 350 XL analyzer having sensors for CO,CO_2,NO,NO_2,NO_x and SO_2.
- For WSOC (water soluble organic carbon) estimation, the quartz filters were extracted in Milli Q water and then analyzed using the Shimadzu VcSH TOC analyzer. The filter punches 1cm x 1.5 cm size or a filter cut of same area is subjected to ultrasonication for 30minutes immersed in 20mL MilliQ. The supernatant is then filtered using 0.22µm disc filters and stored in a centrifuge after making up the volume up to 25mL.The number of filter pieces ranged between two and four as determined by the OC load measured by the thermal-optical transmission instrument.
- Emission factor calculation were made following the carbon balance approach as described in [2].

RESULTS AND DISCUSSION





- The particle loss in connecting tube of multi-arm smoke collector was determined as 2% using a cotton swab.
- Fig 1a. Shows variation of NO_x with respect to time indicated considerably high emissions from traditional mud stove compared to Improved metallic stove (ICS).
- Initially during incipient phase of combustion high NOx emissions can be attributed to addition of 15-20 ml diesel as igniting aid.
- During flaming combustion between 5 to 25 minutes again the NOx emission were high as expected and showed relatively low variation.
- At the end of combustion process that is during smoldering the NOx emissions reduced and showed invariability.
- Fig. 1b shows the variation of CO to CO_2 ratio which is a proxy to characterize combustion as good or bed.
- Again CO/CO2 ratios were high for traditional cook stove compared to IMS during incipient and flaming phase however, the differences were not prominent during smoldering phase of combustion.

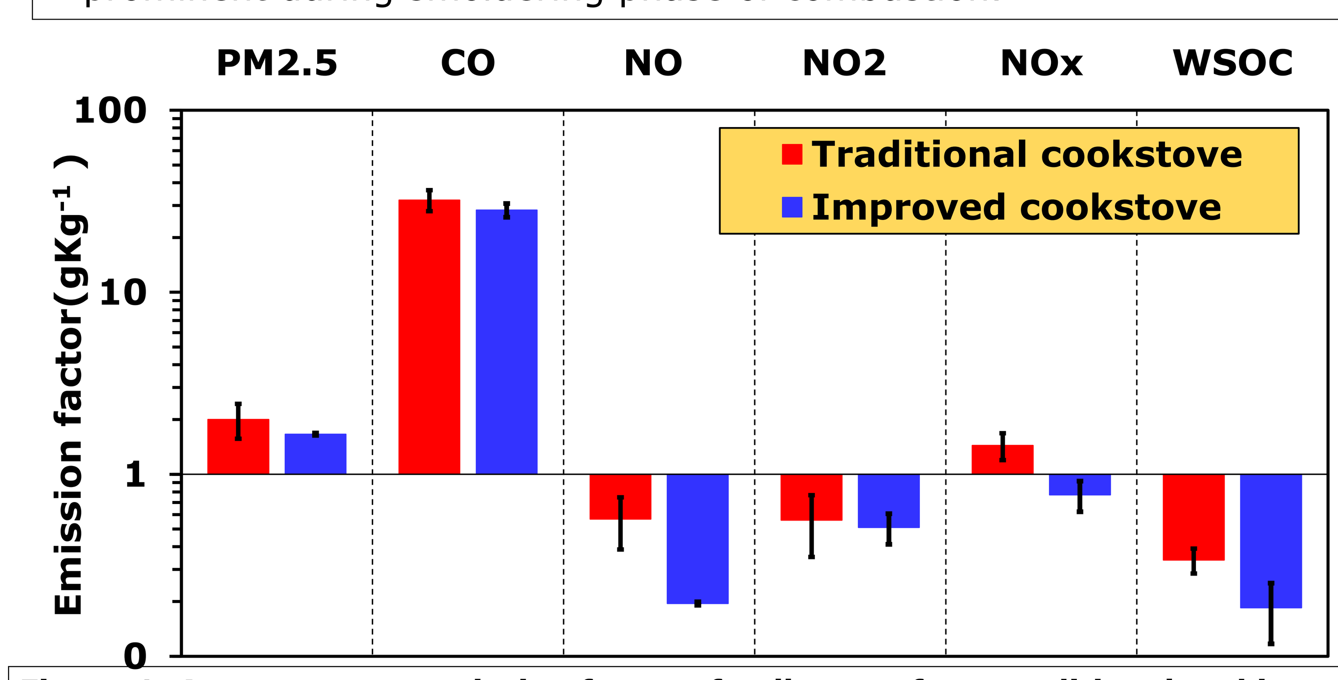


Figure 1. Average mass emission factor of pollutants from traditional and improved metallic stove

Table 1.Emission factors estimated for $PM_{2.5}$, flue gases and WSOC (water soluble organic carbon) in (gKg^{-1})

Cook stove type	Traditional Mud Stove	Improved Metal Stove	Improved/Traditional	Literature Reported Values
Emission factor (gKg^{-1})				
$PM_{2.5}$	2.03 ± 0.44	1.76 ± 0.02	1.15	1.9 ± 0.8[a]
CO	32.3 ± 4.2	26.5 ±2.4	1.13	18 ± 4[b]
NO	0.57 ± 0.18	0.2 ±0.04	2.8	-
NO_2	0.56 ± 0.20	0.6 ±0.1	0.9	-
NOx	1.44 ± 0.24	0.9 ±0.15	1.5	1.17[c]
WSOC	0.34 ± 0.05	0.27±0.07	1.2	-

Habib et al., 2008 [a]; Venkataraman et al., 2001[b]; Zhang et al., 2000 [c]

- Mass emission factor of $PM_{2.5}$, CO, NO_x and WSOC for traditional stove showed little variability among experiments as indicated by coefficient variance (13-22%) (Figure 2, Table 1).
- For ICS mass emission factors of all the pollutants except WSOC showed very little variation among experiments (1-19%) (Figure 1, Table 1).
- Average mass emission factor (g pollutant of emitted per kg of fuel burned) of NO, NOx and WSOC were 2.9, 1.9, 1.8 times respectively higher from traditional stove than ICS (Table 1).
- Other pollutant pollutants $PM_{2.5}$, CO, NO_2 were 10-20% higher from traditional stove compared to ICS.
- The similar emissions of CO from ICS and traditional indicates combustion in ICS was as inefficient as in traditional stove.
- The emission factors of $PM_{2.5}$ and NOx from traditional and ICS were close to the range reported in literature for Indian cook stoves.
- Our emission factors of CO for both the stoves were 1.5-1.8 times higher than values reported in literature.
- The emissions from biomass fuel combustion in stoves are highly sensitive to fuel type, size, moisture content, feeding rate, and burn rate[1-3].
- Overall the emission factor measured using newly developed multi-arm smoke collector are in good agreement with literature.

CONCLUSIONS

The emission factor estimated using the described portable multi-arm sampling system were well in agreement with the range of the values reported in literature[1-5] from laboratory based experiments for each of the pollutant species.

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