The 4th Biennial Partnership for Clean Indoor Air Forum

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BERKELEY AIR MONITORING GROUP

At **Berkeley Air Monitoring Group**, our mission is to protect global health and climate by providing high quality, scientific monitoring and evaluation of appropriate household energy technologies and approaches in less developed countries. We are a social venture based in California, USA, currently working on projects to measure indoor air pollution, fuel use and stove emissions for household energy programs in Asia, Africa and Latin America.

Monitoring and Evaluation Activities:

- Indoor air pollution (IAP) and health
- Carbon credit generation (Gold Standard methodology)
- Household fuel use
- Technology adoption and usage
- Sole vendor of the UCB Particle Monitor
- Instrument procurement
- Greenhouse gas emissions
- Household socioeconomic assessment

In-field charcoal stove emission factors and indoor air pollution in Nairobi, Kenya

Introduction and Objectives

Charcoal is widely used in poor communities in Kenya and across Africa, but its health and climate impacts, and the relationship between the two, are not well understood. In this study, we determined in-field emission factors for charcoal stoves in realistic household settings and simultaneously measured indoor air pollution levels. Emissions indicate the amount of air pollution produced directly by a stove, while indoor air pollution concentrations indicate the amount of pollution inside a house (particularly in the kitchen).

Methods

- 4 households; 3 controlled cooking tests (cooks prepared ugali) and 1 typical evening meal were performed in each household
- New Jiko improved charcoal stove & charcoal given to each household
- Emissions collected directly above stove using a 3-pronged aluminum sampling probe. Sample split into two lines: (1) an emission sample collection bag and (2) real-time CO-CO_2 and SO_2 monitors. A simultaneously collected sample was used to correct emissions for background concentrations in the kitchen
- Real-time indoor air quality measurements of $PM_{2.5}$, SO_2, CO, HCHO taken concurrently. Instruments installed 1.0 m from the center of the stove and 1.5 m above ground

Results

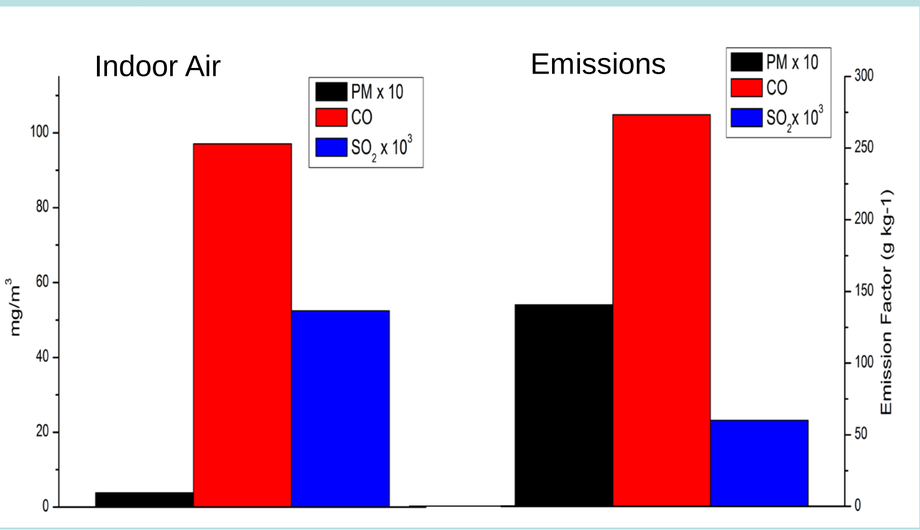
Figure 1. Stove Emissions

	Unit	CCT	Meal	IPCC
# HHs	---	12	4	---
NCE	%	81.2 ± 2.9	75.6 ± 3.4	---
CO_2	g/kg	2543 ± 113	2394 ± 103	3304*
CH_4	g/kg	14.3 ± 5.6	15.0 ± 3.8	10**
CO	g/kg	273.2 ± 54.5	350.5 ± 68.5	(134)***
TNMHC	g/kg	29.9 ± 13.6	53.4 ± 10.2	(7)***
PM	g/kg	14.07 ± 5.31	15.89 ± 7.69	---
SO_2	g/kg	0.06 ± 0.04	0.05 ± 0.05	---

Figure 2. Indoor Air Pollution

	Unit	CCT	Meal	All Day	WHO Guideline
# HHs	---	12	4	4	-----
$PM_{2.5}$	µg/m³	385 ± 96	294 ± 271	156 ± 30	75* (24-hr. Interim Target 1)
SO_2	ppm	0.02 ± 0.05	0.02 ± 0.02	0.00 ± 0.00	0.19* (10-min.)
CO	ppm	85 ± 35	96 ± 25	36 ± 13	90* (15-min.)
HCHO	µg/m³	64 ± 20	NA	NA	130** (15-min.)

Figure 3. Comparison between Indoor Air Pollution and Stove Emissions



- Figure 1 shows the in-field charcoal stove emission factors of several air pollutants during the controlled cooking tests (CCT) and the typical evening meal, and compares them to the IPCC default values. Also shown is the nominal combustion efficiency (NCE), the percentage of fuel carbon emitted as carbon dioxide (CO_2). Perfect combustion has an NCE of 100%.
- Figure 2 shows average fine particulate($PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), and formaldehyde (HCHO) concentrations during the controlled cooking tests (CCT) and the typical evening meal and compares them to the World Health Organization (WHO) Air Quality Guidelines.
- Figure 3 shows the kitchen concentrations and emissions data side-by-side for PM, SO_2 and CO during the controlled cooking tests. As expected, though this is rarely documented in actual houses, they show the same general pattern.

[TNMHC= Total non-methane hydrocarbons]

Discussion

- As shown in Figure 1, in-field emissions of CO, TNMHC, and PM (black carbon) from charcoal stoves are significant. Current methodologies for carbon credit estimation only include CO_2 and CH_4, thereby overlooking the impact of these other greenhouse gases.
- Emission factors (EF) observed in this field study were not systemically different from IPCC default values for residential charcoal (CO_2 EF lower, CH_4 EF higher).
- Particulate matter continues to be the most significant health threat, even for charcoal stoves. As seen in Figure 2 above, SO_2, CO and HCHO kitchen concentrations were at or below the WHO guidelines in these tests, whereas $PM_{2.5}$ levels are significantly higher.
- This study points to the value of monitoring both controlled cooking tests and typical, uncontrolled meals in households since there were some variations between the two.
- This study design is useful for modeling the relationship between emissions and indoor air concentrations and for guideline setting.

Next Steps

- Field data such as this will be used to inform future stove standards and to support the inclusion of all relevant greenhouse gases in carbon offset programs.

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