Improved Biomass Stoves and Improved Cooking Practices Contribute to Lowering PM2.5 Exposure in Addis Ababa, Ethiopia

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INTRODUCTION AND MOTIVATION

Globally, approximately 2.4 billion people cook using biomass fuels (WHO, 2023). This fuel, in combination with inefficient stoves, leads to millions of deaths per year, primarily of women and children who are most impacted by cooking emissions. There are many efforts underway to develop and make available improved and clean cookstoves that burn more efficiently, whether using traditional or improved fuels. These stove/fuel combinations typically perform well under test conditions in the laboratory or when being demonstrated in household kitchens, but their promise for diminishing health effects can only be realized if they are consistently operated using best practices. Here we investigate the impact of specific cooking practices on indoor PM2.5 with a clean (Tier 4) fan-forced gasifier stove burning biomass pellets in multiple households in Addis Ababa, Ethiopia. The stoves have been in use for months in these households, providing an accurate snapshot of actual usage.

CHARACTERIZING COOKING EVENTS

Stoves and Pellets: Tier 4 fan-forced gasifier (Mimimoto) stoves were distributed to households in 2018 and 2020. Pellets made from mixed biomass, including wood shavings, coffee husks, spent coffee grounds, coffee pulp, and other miscellaneous products, are provided for cooking. Charcoal stoves are various types of Lakech traditional stoves. Wood stove are 3-stone fires.

PM2.5 Measurement: PATS+ (Berkeley Air) instruments measuring PM2.5 with 1-min time resolution. PATS+ units respond within 5% of each other and are uncorrected as shown here. Sampling is done in multiple locations in the cooking area. Measurements above the stoves are highlighted here.

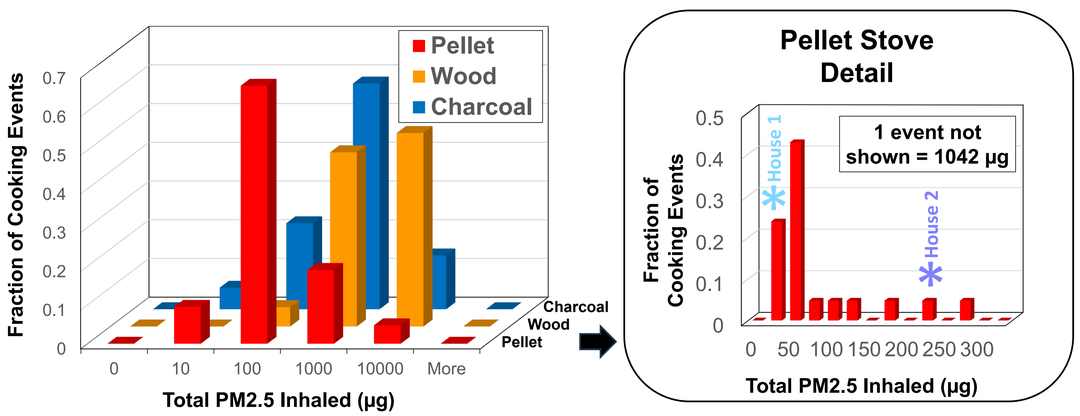
CO Measurement: Lascar Electronics EL-USB-CO300 Carbon Monoxide Data Logger with 1-min time resolution.

Cooking Events: Cooking events are identified in one of two ways: 1) via notes taken by a researcher about when the fire was lit and extinguished, or 2) using a Stove-Use Monitor (SUM) to identify these times via change in slope of the stove external temperature as a function of time. In all cases, cooks were cooking dishes of their own choice in their own kitchens, with no effort to standardize.

Dosage Calculation: Dosage is the integral of the PM2.5 concentration over the duration of the cooking event multiplied by average breaths/minute and average breath volume for an adult female.

PM2.5 Exposure During Cooking Events

Comparison of Different Stove/Fuel Types



Exposure to PM2.5 is significantly minimized during cooking events using the fan-forced gasifier stoves with pellet fuel, compared to cooking with charcoal or wood stoves. However, there is a range of exposures with the improved stove due to differences in stove operation as illustrated by individual events measured in House 1 and House 2.

COOKING EVENT INFORMATION

The fan-forced gasifier stove stove decreases emissions and limits the duration of cooking events, determined by the size of the pellet combustion chamber. Cooking event information from Addis Ababa, Ethiopia, is shown below.

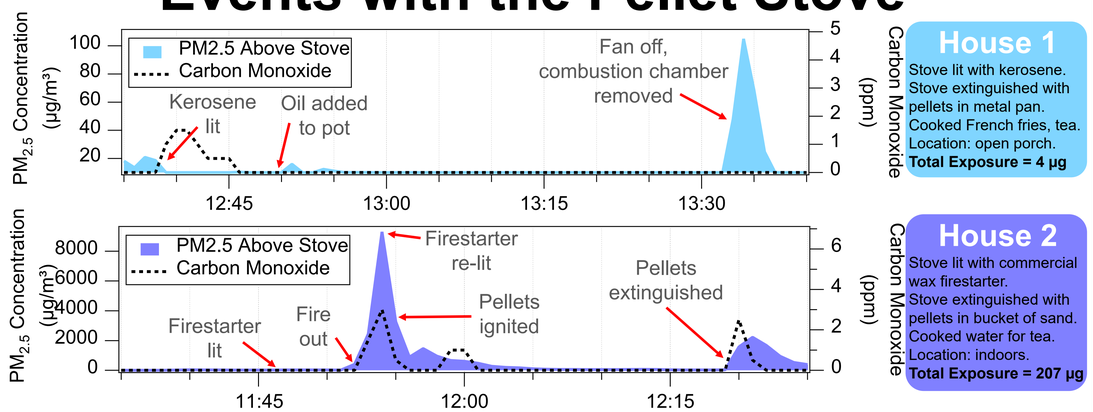
Stove/Fuel	Number of Events Recorded	Average Duration (hh:mm)	Average PM2.5 Exposure (µg)	Stove Thermal Efficiency
Fan-forced gasifier/Pellet	21	01:10	111	~65%
3-Stone fire/Wood	20	05:29	1272	~20%
Lakech/Charcoal	36	05:45	778	~35%

The World Health Organization's recommended outdoor PM2.5 level of 15 µg/m^3 corresponds to 129 µg of PM2.5 exposure over 24 hours, for an average female.

VARIABILITY IN PELLET STOVE USE

A comparison of emissions during specific cooking events highlights the differences in how individual practices can impact stove emissions, and therefore exposure to PM2.5 from the emitted smoke. How the stove is lit and extinguished, and how the fan is set at those times, are key variables that determine PM2.5 emissions.

PM2.5 Emissions During Cooking Events with the Pellet Stove



Measurement of PM2.5 emissions during cooking events can pinpoint the activities that contribute the most to PM2.5 emissions. House 2's cook was less careful with the stove's fan settings than House 1's, interrupting ignition and contributing to high emissions when the pellets burned out. Cooking indoors (House 2) contributed to high PM2.5 levels, compared to cooking on a well-ventilated porch (House 1).

CONCLUSIONS

Clean stoves, such as fan-forced gasifier stoves burning pellets, significantly decrease the exposure of cooks during typical cooking events, compared with charcoal and wood stoves. However, it is not enough to provide cooks with clean stoves and fuels. Ongoing training and sharing of best practices, to ensure that the users are not developing practices that cause significantly higher emissions, is critical and can significantly reduce PM2.5 exposure.

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