Personal and area concentrations of CO and $PM_{2.5}$ in charcoal-burning households in peri-urban Rwanda

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The overarching objective of our study aims to characterize the effect that improved cookstoves (ICS) may have on social welfare, health outcomes, regional forest use, and household energy. As a first step, we analyze the exposure monitoring data collected during the baseline round of our study. We quantify personal CO concentrations for a large sample of charcoal-burning households over a 24-hour period. For a subset of the sample, we quantify personal and area concentrations of HAP (CO + $PM_{2.5}$) over a second, non-consecutive 24-hour sampling period. We find average daily concentrations for CO and PM 2.5 to be between ~5 and ~20 ppm and between ~150 and ~700 $\mu g/m^3$ respectively, consistent with other findings. Approximately 25% of personal HH measurements exceed 24-hour WHO AQC guidelines, in addition to 73% of HH area measurements. We compare repeated CO measurements taken in the same household during two non-consecutive sampling periods, spanning from a few days to a few weeks apart, and find that our individual, randomly sampled 24-hour measurements vary by a factor of 2 to 3. This may suggest that utilizing solely a single-day monitoring period to detect changes in emissions at a household level may not yield significant results; Instead intervention studies should rely on a large number of households to measure a collective change. Finally, we search for variables in our data ranging from household size, fuel type and quantity, indoor vs. outdoor cooking, and health outcomes that may be predictive of emission levels to provide information for structuring future ICS interventions.

Quantifying household air pollution in charcoal-burning households in peri-urban Rwanda

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Introduction

- In sub-Saharan Africa, household air pollution (HAP) from solid fuels is the sixth largest contributor to the burden of disease. Exposure to HAP is primarily attributable to the burning of biomass fuels and the persistence of traditional cooking technologies. Improved cookstoves and cleaner biomass fuels are widely regarded as a possible solution.
- The purpose of this study is to investigate how improved cookstoves may lessen the health, forest, and climate strain that results from traditional technologies. As a first step, we present the baseline measurements from the multi-year study.

Fig. 1: Traditional charcoal cookstoves in a kitchen. The red cylinders attached to the stoves are temperature data loggers that serve as stove use monitors.

Gisenyi, Rwanda

- One of the most population-dense and biomass-deficient settings in sub-Saharan Africa.
- Biomass and charcoal account for 99% of all Rwandan cooking energy.

wikipedia.org helainainrwanda.wordpress.com

Fig. 2: Rwanda is located in central east Africa. Our study site is in Gisenyi, which is located in Rwanda's Western Province.

Cook Stoves

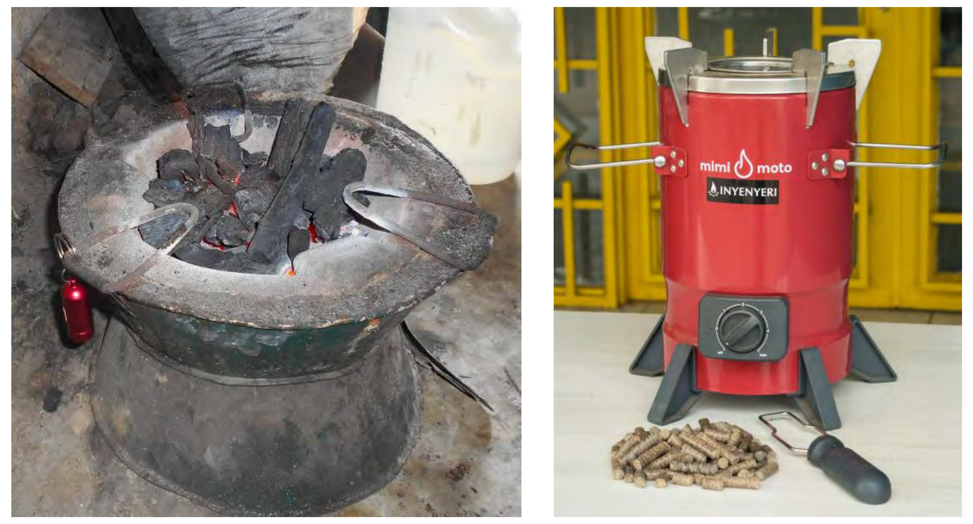

Fig. 3: Traditional charcoal stove and an improved cookstove (pellet-burning Mimi Moto)

Study Design

- Monitor HAP of cooks and kitchens for 24-hour period annually from 2015 to 2018
- Introduce improved cookstoves in intervention households after baseline measurements

Fig. 4: Monitoring HAP in a traditional cookstove kitchen during baseline

Monitoring equipment

- Carbon monoxide (CO) via data loggers and fine particulate matter (PM2.5) via impactors
- Monitoring equipment in backpack for cooks and on tripod in kitchens

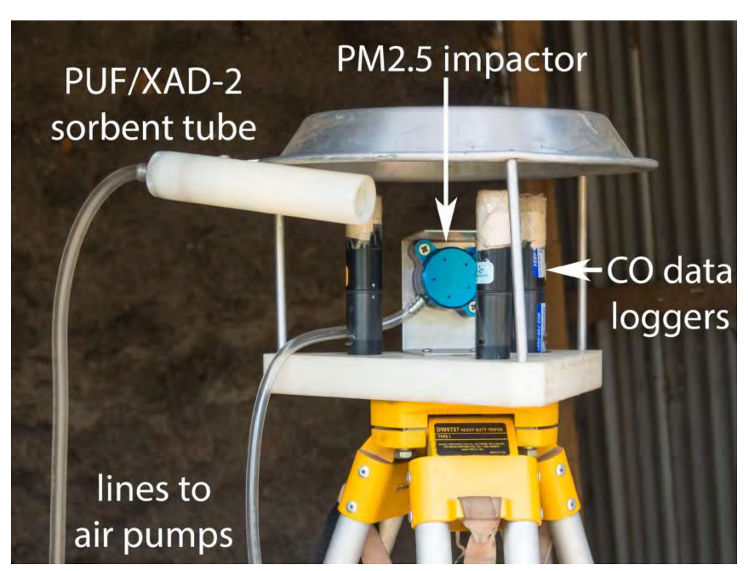

Fig. 5: Tripod-mounted monitoring equipment used to measure HAP in kitchens

CO Exposure Trends

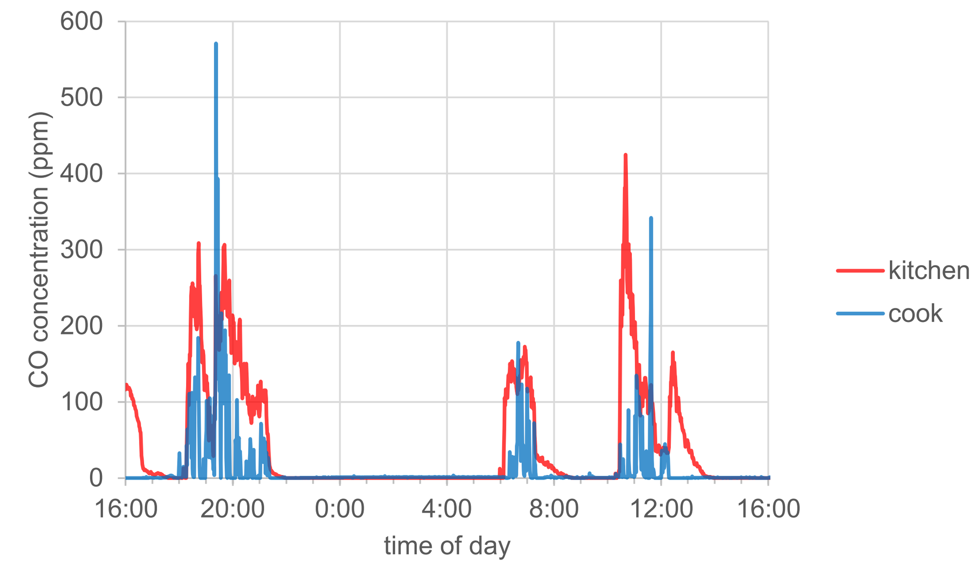

Fig. 6: CO concentrations measured once a minute over a 24-hour period in a single household. The difference between the cook and kitchen peaks illustrates how the cook moves in and out of the kitchen while cooking. Monitoring only the kitchen environment will provide a limited picture of cook exposure.

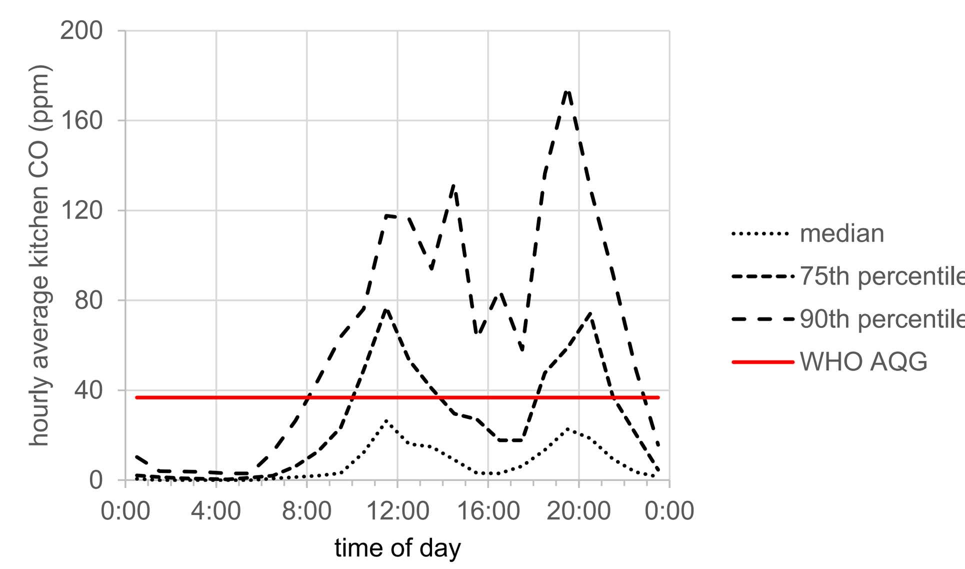

Fig. 7: Hourly average CO concentrations in kitchens for 54 households. Hourly averages are obtained by averaging the once-a-minute measurements for each household. The WHO Air Quality Guideline (AQG) is the pollutant concentration considered to have no or minimal impact on health. The 1-hour average AQG for CO is 35 mg/m³.

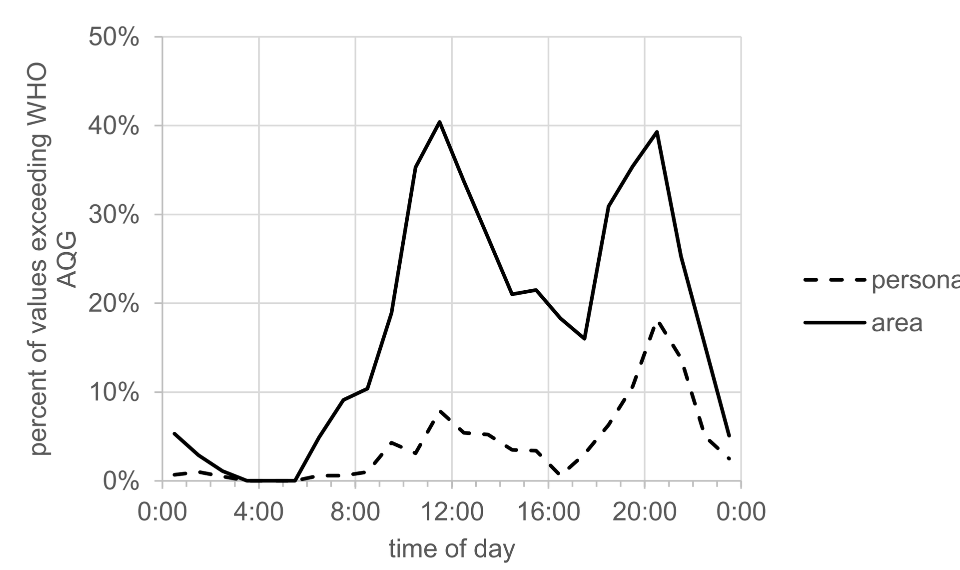

Fig. 8: Percentage of hourly average CO concentrations for cooks and kitchens that exceed the WHO AQG by time of day.

High Concentrations

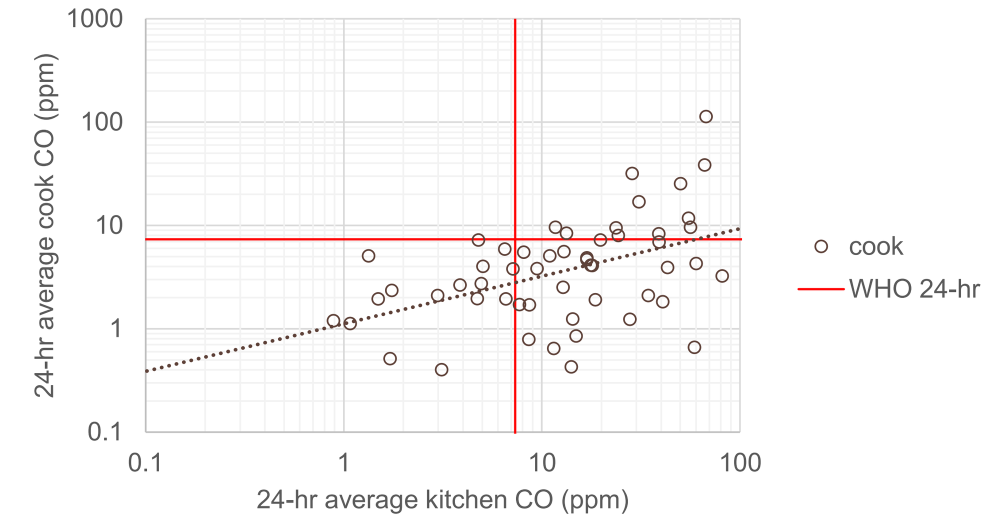

Fig. 9: 24-hour average CO concentrations for cooks and kitchens in 54 households. The 24-hour average WHO AQG (7 mg/m³) is shown for comparison.

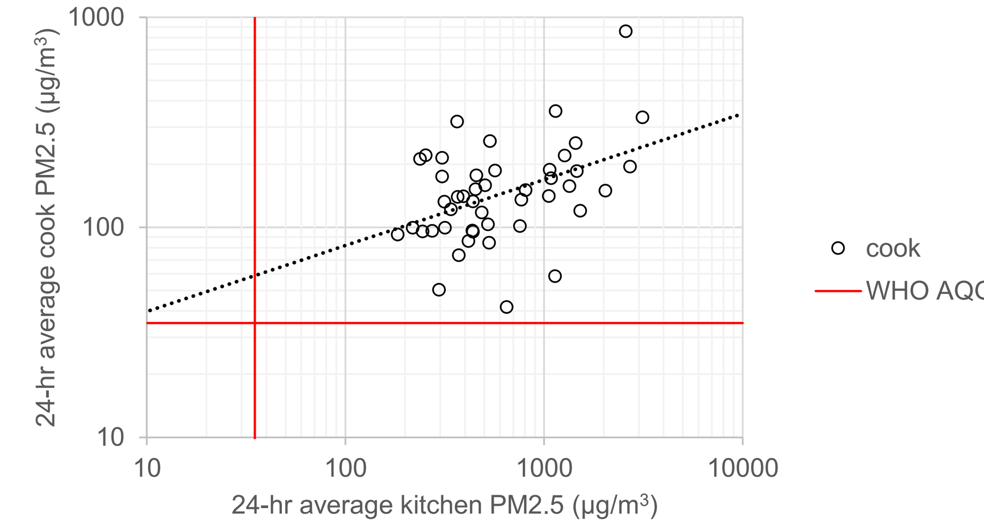

Fig. 10: 24-hour average PM2.5 concentrations for cooks and kitchens in 46 households. The WHO AQG (35 µg/m³) is shown for comparison.

Repeated Measurements

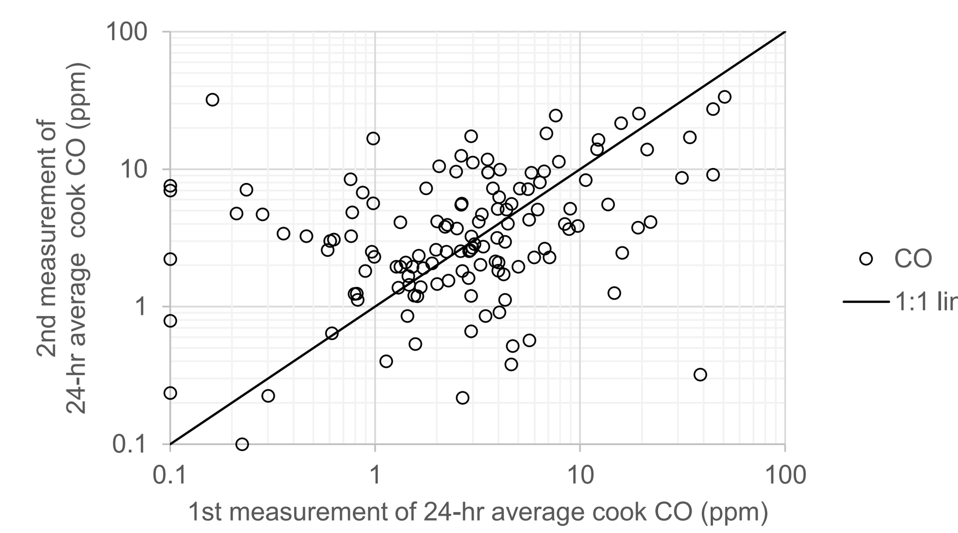

Fig. 11: Comparison of 24-hour average CO concentrations for the 134 households where two, non-consecutive CO measurements were made (up to 38 days apart). The measurements in the middle range (1 to 10 ppm) differ on average by a factor of 2.5. There is no trend in the differences between the measurements as a function of the time lag between the measurements. This variability will make it difficult to measure meaningful HAP reductions at a household level. The intervention study will rely on results from a large sample to determine if significant HAP reductions are achieved.

Summary

- ~25% of cook CO concentrations, ~73% of kitchen CO concentrations, and all cook and kitchen PM2.5 measurements exceed 24-hour WHO air quality guidelines
- Randomly sampled 24-hour average CO measurements vary by a factor of 2 to 3
- Preliminary evidence of "stove stacking" (Fig. 12) seen during round two of data collection

Fig. 12: Example of "stove stacking" where intervention households adopt the improved Mimi Moto cookstove, but continue to use traditional stoves. This makes it difficult to achieve the HAP reductions that are hoped for through the adoption of improved cookstoves.

Forthcoming Analysis

- Multi-variate analysis of household variables that might be related to HAP concentrations (e.g., household size, stove and fuel type, indoor vs. outdoor cooking, and health outcomes)
- Additional data collection in 2017 and 2018

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