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Using objective measures of stove use and indoor air quality to evaluate a cookstove intervention in rural Uganda

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ABSTRACT

Exposure to combustion byproducts from cooking is a major health concern globally. Alternative stoves may reduce the burden of disease associated with exposure to household air pollution. We subsidized Ugastove-brand rocket stoves to 54 households in six rural Ugandan villages. We monitored kitchen concentrations of fine particles ($PM_{2.5}$) and carbon monoxide (CO) before and one month after introduction of the Ugastove. Temperature data-loggers were affixed to each Ugastove and to the traditional stove (three-stone fire) during the 1-month Ugastove acclimation period to record temporal patterns in stove use and adoption. Household surveys were administered to collect household information that may impact stove use or indoor air quality. $PM_{2.5}$ kitchen concentrations were 37% lower after introduction of the Ugastove (mean reduction: 0.68 mg/m^3; 95% confidence interval [CI]: 0.2–1.2; $p < 0.01$). Changes in CO concentrations were small (8% lower; mean reduction: 1.4 ppm, 95% CI: −5.2–7.9) and not statistically significant. During the 1-month acclimation period, 47% of households used primarily the Ugastove, 12% used primarily the three stone fire, and 41% used both stoves in tandem. $PM_{2.5}$ concentrations were generally lowest in households that used primarily the Ugastove, followed by households that used stoves in tandem and that primarily used a three-stone fire. In summary, introduction of the Ugastove in 54 rural Ugandan households was associated with modest reductions in kitchen concentrations of $PM_{2.5}$ but not CO. Objective measures of stove use reveal that short-term stove use varied by household.

Introduction

Roughly half of the global population (including ~80% of rural households in the developing world) relies on biomass fuels for cooking (IEA, 2006). Exposure to the byproducts of incomplete combustion is associated with numerous adverse health outcomes including chronic obstructive pulmonary disease, acute respiratory infections (especially in children), higher blood pressure, lung cancer, low birth weight, infant mortality, and pneumonia (Baumgartner et al., 2011, 2014; Bruce et al., 2000; Dherani et al., 2008; Ezzati and Kammen, 2002; Kurmi et al., 2010; Smith-Siverstsen et al., 2009). Exposure to indoor air pollution correlates with cooking practices; in low-income countries cooking is primarily conducted by women and children (Balakrishnan et al., 2004; Bruce et al., 2000). The World Health Organization estimates that indoor air pollution is the 4th most important risk factor globally for morbidity (108,084,000 Disability-Adjusted Life Years; Lim et al., 2012).

Switching to cleaner fuels is a promising strategy for improving indoor air quality (Grieshop et al., 2011; Siddiqui et al., 2009). However, in rural areas of developing countries, access to (and ability to pay for) clean fuels is often limited. Strategies to improve indoor air quality therefore generally focus on improved combustion (i.e., more efficient stoves) or altering the cooking environment (e.g., increased ventilation or constructing detached kitchens) (Hutton et al., 2007). Emissions for a variety of alternative-design stoves have been characterized in a controlled setting (Bhattacharya, et al., 2002; Jetter and Kariher, 2009; Roden et al., 2006, 2009). Field measurements of indoor air quality for community-scale alternative stove interventions have been reported in many areas of the world (Albalak et al., 2001; Edwards et al., 2007;

Abbreviations: CO, Carbon monoxide; $PM_{2.5}$, Particulate matter of 2.5 microns or less; UCB, University of California—Berkeley Particle Monitor; URF, Uganda Rural Fund.

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Smith et al., 2007). Exposure assessments have focused on a variety of strategies, including estimating kitchen concentrations before and after interventions (Chengappa et al., 2007; Dutta et al., 2007; Masera et al., 2007; Pennise et al., 2009) and personal sampling of household members during a stove intervention (Clark et al., 2010; Northcross et al., 2010).

Stove use and adoption are often evaluated using information from self-report surveys; a limited number of interventions use objective measurements based on recording stove temperatures (Ruiz-Mercado et al., 2008; Smith et al., 2007). Studies of adoption rates are sparse and the factors that may influence adoption are largely unknown (Lewis and Pattanayak, 2012); there is a significant need for better collaboration between public health officials and researchers to gain clarity on what drives cookstove adoption (Gall et al., 2013). Few studies integrate real-time objective measurements of both air pollution and stove use (Ruiz-Mercado et al., 2011).

This study evaluates the introduction of a wood burning rocket stove made by Uganda Stoves Manufacturers Ltd. (hereafter referred to as the Ugastove) to 54 households in six villages in rural southwestern Uganda. We assess the effectiveness of this intervention via before-and-after measurements of indoor air quality (fine particles [$PM_{2.5}$]; carbon monoxide [CO]) and short-term (i.e., 1-month) stove use. Our study makes useful contributions in two areas: (1) deploying integrated objective measurements of indoor air quality and stove use, and (2) evaluating a widely distributed, locally manufactured stove in Uganda.

Data and methods

Study site description

This study was conducted in villages surrounding Kyetume Village near Masaka, Uganda (population: ~500) during June–August of 2010. Kyetume is located in southwest Uganda, approximately 50 miles west of Lake Victoria and 40 miles north of the Uganda-Tanzania border (Fig. 1). The villages lack access to basic infrastructure (e.g., drinking water, sanitation systems, health care). Electricity is available, but intermittently, in only one of the villages (Kyetume). Residents in the study area use primarily three stone fires for cooking.

Stove selection

During an assessment trip in January of 2010, we introduced four stoves to community leaders and focus groups: two wood-burning rocket stoves (Ugastove; StoveTec), a charcoal stove (Ugastove-brand), and a solar oven (Minneapolis Solar Oven Society). Community members showed an overwhelming preference for the wood burning stoves. Between the two wood-burning stoves, the Ugastove was preferred because it is larger (most households in rural Uganda are large: ~10 people), has a fixed pot skirt (to prevent spills), and is the tallest of the alternative stove options (less bending over while cooking). Based on community feedback we chose the wood fueled

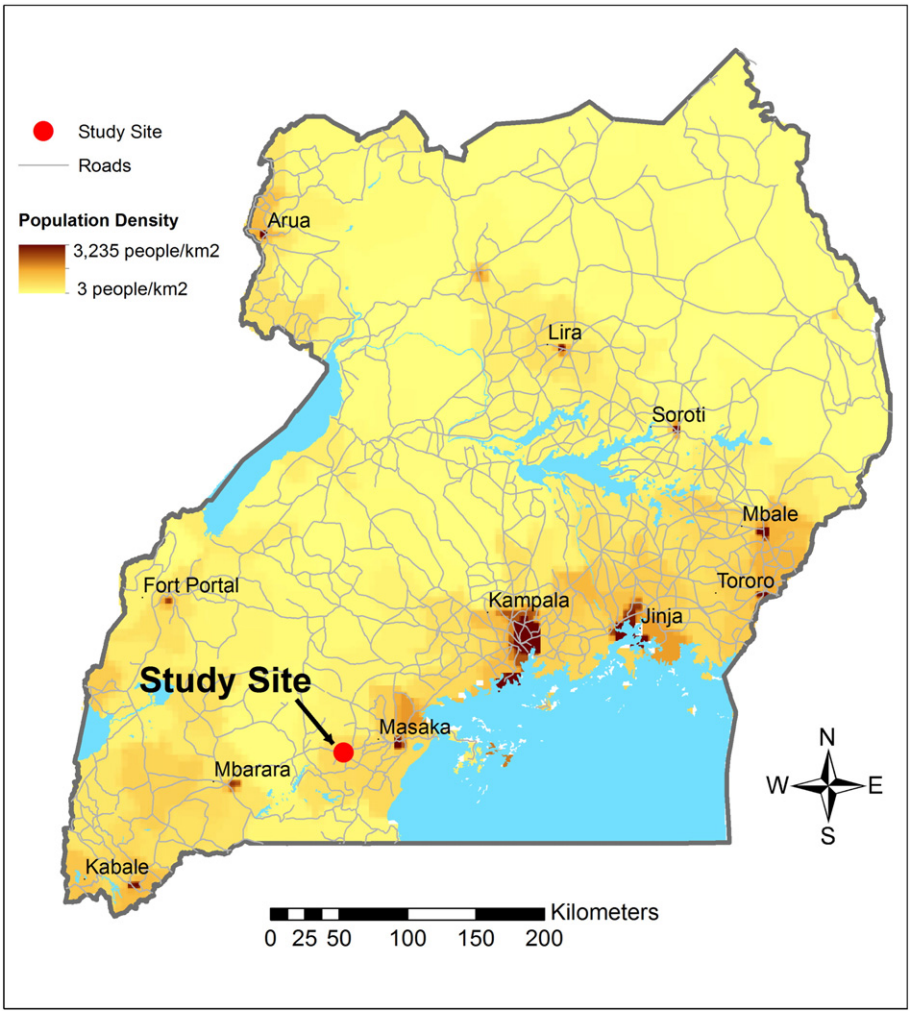

Fig. 1. Location of the study site (Kyetume Village and surrounding villages).