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Field-based safety guidelines for solid fuel household cookstoves in developing countries

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ABSTRACT

The burning of solid fuels for cooking creates significant adverse health, social, and economic consequences for more than three billion people worldwide. Recognizing this issue, many groups have worked to develop improved stoves that increase fuel efficiency, decrease fuel use, and reduce particulate emissions. Less attention has been given to developing a standardized process for rating cookstove safety and reducing cookstove hazards. This paper identifies common cooking hazards and seeks to reduce cooking injuries by proposing ten field-based safety guidelines for solid fuel stoves. Each guideline describes an underlying safety principle and is accompanied by a test protocol and a metric to rate stove safety. This incremental rating system enables stove designers, donors, and consumers to track and promote stepwise safety improvements. The protocols use low-cost equipment to allow the many manufacturers of handcrafted cookstoves to assess safety without using sophisticated testing facilities and expensive equipment.

Introduction

Cooking over an open fire or on an ad hoc stove poses unnecessary hardship including disease, injury, pollution, excess time spent gathering fuel, deforestation, and high fuel costs relative to income for more than three billion people (Alam et al., 2006; Barradas, 1995; Ezzati et al., 2000; Grainger, 1982; Johnson and Bryden, 2012a; Mahat, 2003; Mathers et al., 2006; Garcia-Moreno, 2009; Smith et al., 2004; Smith et al., 2010; WHO, 2008; WHO, 2011a; WHO, 2011b; WHO, 2014). This global problem is realized locally in remote communities that, for example, rely on wood burning domestic cookstoves that contribute to over three-quarters of all village energy use with far-reaching effects that permeate daily life—e.g., women spending 65% of their day preparing food, cooking, cleaning, and gathering wood from distances of up to 8 km per round trip (Johnson and Bryden, 2012a; Johnson and Bryden, 2012b). In addition the particulate and carbon monoxide emission of cookstoves pose significant health and safety risks to the users. To address these problems, numerous private, governmental, and non-governmental organizations have worked to develop improved cookstove designs for many years. This work has generally focused on increasing stove efficiency, improving heat transfer to the cooking surface, and decreasing indoor air pollution (Bryden et al., 2003; Chengappa et al., 2007; Mukunda et al., 1988; Prasad et al., 1985; Smith et al., 2004). A variety of test methods and metrics are available for cookstove thermal efficiency and emissions testing, and a number of testing efforts focused on thermal efficiency and emissions have been reported (Jetter and Kariher, 2009; MacCarty et al., 2010). Several investigators have examined the human health effects from exposure to particular matter and carbon monoxide emissions and the safety of cookstoves based on the cookstove emissions (Alnes et al., 2014; Ezzati et al., 2000; Grabow et al., 2013; Smith et al., 2004; Smith et al., 2010; WHO, 2014). In contrast, little attention has been given to developing a structured process to rate and improve cookstoves on direct-contact hazards that cause burns, cuts, and scalds. That latter safety concern lags behind studies of emissions and exposure, and is therefore the sole focus of this work to help bring contact-related safety concerns to the forefront of cookstove discussions.

Solid fuel cookstove designs and production techniques are highly varied (Fig. 1), and the heterogeneity poses a challenge to creating a universally applicable stove safety test procedure. To date, many of the cookstoves manufactured have been hand-crafted and produced in small volumes by local artisans, household businesses, and workshops. Only recently are solid fuel household cookstoves being mass-produced in high volumes for use in the developing world.

Improving the safety of handcrafted cookstoves is a challenging issue that is unlikely to be addressed in the near term by national product standards. National and international stove safety standards are based on the premise that stoves are produced in high volumes at close tolerances using industrial equipment. Although these standards are suitable in industrialized economies with testing laboratories and regulatory bodies, the protocols and approval processes are poorly

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Fig. 1. Basic solid fuel cookstoves (clockwise from upper left): wood stove made from clay, wood stove made from metal, coconut husk and wood stove made from clay and bricks, charcoal stove made from metal, charcoal stove made from metal, rice hull stove made from metal.

suited for use by small-scale producers in developing countries that face financial and logistical barriers to laboratory stove safety evaluation. To reach the highly distributed network of low-volume stove producers, safety tests would ideally be completed in the field at low cost.

This paper introduces ten field-based safety guidelines for solid fuel household cookstoves. Each guideline is accompanied by a safety principle, a testing protocol, and a metric to rate stove safety for direct-contact hazards. The protocols use low-cost equipment to allow the numerous manufacturers of hand-crafted stoves to assess safety in the absence of expensive testing facilities and equipment. An incremental rating system is used to allow stove designers, donors, and consumers to track and promote stepwise safety improvements. These procedures and ratings facilitate the consideration of cookstove safety during engineering design alongside other cookstove merits such as efficiency and reduced emissions. Although the focus of this work is on hand-crafted stoves, the protocols can be applied to manufactured stoves, and testing may occur in a laboratory environment. The guidelines provided here are focused on cookstoves and are not intended to be applied directly to stove whose primary purpose is space heating.

Background

A limited amount of statistical data is available on the hazards resulting in injuries recorded from solid fuel cookstoves (Diekman et al., 2014; Mathers et al., 2006; Garcia-Moreno, 2009; Peck et al., 2008; WHO, 2008; WHO, 2011a; WHO, 2011b; Barradas, 1995). Much of what is known is qualitative and anecdotal. This is not surprising given that rural households—often without access to clinics that record injury statistics—are the primary users of solid fuels for cooking and heating (IEA, 2010). Existing studies identify injuries such as burns to the hands from contact with open flames, burns to the legs from clothing fires, morbidity related to procuring and carrying wood, and scalds from heated liquid spilling from the cooking vessel (Alam et al., 2006; Forjuoh et al., 1995; Han et al., 2005; Mock et al., 2008; Wickramasinghe, 2003; WHO, 2011b). These are just a few types of injuries related to collecting fuel, cooking, and cleaning up after cooking. Yet most of these hazards pertain to the local cooking environment or kitchen. Consider the wood cooking fire placed on the floor of a small kitchen as shown in Fig. 2. Several hazards are apparent:

- Long clothing can catch fire resulting in severe burns to the legs (Fig. 3a).
- Long hair can catch fire while cooking and working around the cookstove.
- Children can fall into the fire and be severely burnt on the hands and arms (Fig. 3b).
- Children can grab pots and overturn heated contents onto themselves (Fig. 3c).
- The surrounding wood and straw can catch fire from a stray ember.

Fig. 2. Cooking on an open fire in Mali.