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An evaluation of a biomass stove safety protocol used for testing household cookstoves, in low and middle-income countries

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ABSTRACT

To mitigate the impact of excess pollution, deforestation, and injuries attributable to cookstoves in low and middle income countries, humanitarian and private sector organisations have made a commitment to increase the adoption of improved cookstoves (ICS) to 100 million households by 2020 . In order to evaluate the safety of these ICS for the end users, a ten-test "biomass stove safety protocol" (BSSP) has been developed by the Global Alliance for Clean Cookstoves (GACC). However, there is no published evidence that this protocol has been independently assessed or benchmarked. This study aimed to determine whether the BSSP is fit for purpose such that, it will produce repeatable safety ratings for a range of cookstoves when performed by different testers. Results indicated that the scores for each stove varied considerably between each of the six testers with only one of five ICS receiving the same overall safety rating. While individually some tests produced relatively coherent scores, others led to large discrepancies. We conclude that although BSSP is an important starting point in highlighting the need for stove safety assessment, there are some aspects of the protocol that require further development to ensure that it can be reliably replicated by different testers.

1. Introduction

Although there are no reliable global statistics on the number of fatalities associated with burns sustained during cooking, the World Health Organisation (WHO) reports that fire-related burns account for over 300,000 deaths per year (Mock et al., 2011). The burden of these injuries disproportionally affects the world's poorest populations with 95% of fire-related deaths occurring within low and middleincome countries (LMIC) (Mock et al., 2008). For economically fragile households, injuries resulting in death or disability place a long-term financial burden onto families (Mock et al., 2008; Golshan et al., 2013). The use of open fires and crudely assembled ground-level cookstoves is a dominant factor associated with burn injuries within LMIC, particularly within Sub-Saharan Africa and Asia (Justin-Temu et al., 2008; Ndiritu et al., 2006; Zwi et al., 1995; Outwater et al., 2013; Hyder et al., 2004; Albertyn et al., 2006; Peden et al., 2008).

At present, three billion people worldwide rely on the combustion of biomass on open fires and inefficient stoves as a primary source of household energy (Global Alliance for Clean Cookstoves, 2015a (GACC)). Approximately 50% of households worldwide and 90% of rural households use solid fuels for cooking or heating (Kammen, 1995; Desai et al., 2004). These forms of energy production can generate significant health, social, and economic problems for low–income families in developing nations. The use of traditional stoves have been linked to excess pollution, increased time spent gathering fuel, deforestation, injury, respiratory diseases, and high fuel costs (Jones, 2015; Simon et al., 2014; WHO, 2014; Thomas et al., 2015; Kurmi et al., 2010). Since the 1970s, a number of state and non-governmental organisations have aimed to alleviate these problems through the dissemination of "improved" cookstoves (ICS) (Sesan, 2012; Kshirsagar and Kalamkar, 2014). Their designs often focus on increasing fuel efficiency, decreasing fuel use and reducing the emissions of harmful particles rather than the immediate safety for the user.

As humanitarian organisations continue to develop a variety of more refined cookstoves, the need for international standards to rate stove performance has been expressed (GACC, 2012). In February 2012, a group of international organisations and stakeholders joined together to produce an International Workshop Agreement (IWA) (GACC, 2012). The aim of the IWA was to create a framework that was easy for governments, donors, and investors to make decisions and measure progress of cookstove technologies (GACC, 2012). The IWA allocates cookstoves into a tier system based on four indicators: efficiency, indoor emissions, total emissions, and safety. Stoves are rated for each indicator separately and thus may fall into one or more of the tiers depending

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on their individual test performance. Tier 4 represents “best” and tier 0 represents “poor” performance outcomes.

The protocol recognised by the IWA to measure stove safety was developed by Johnson in 2005 (Johnson, 2005). Until this point, research addressing the issue of cookstove safety was limited to the users' exposure to particulate matter and the link to respiratory diseases rather than injuries associated with the direct contact and use of the stoves (O'brien, 2006, Curtis, 2006; Adkins et al., 2010).

It should be noted that at the time this study was conducted, Johnson's (2005) protocol for testing safety was the only published method of risk analysis. Subsequently, the protocol has been developed by the GACC and renamed “biomass stove safety protocol” (BSSP) (GACC, 2015a). The methods, and majority of the wording, that form the BSSP come directly from Johnson's (2005) thesis (GACC, 2015a). Any variation between Johnson's (2005) original protocol and the updated BSSP guidance will be highlighted within this paper.

The BSSP evaluates cookstove safety through ten independent tests (GACC, 2015a). The tests were designed to capture hazards that expose the user to burns and scalds, lacerations and abrasions, and house fires and property loss (Johnson, 2005; Johnson and Bryden, 2015). Each test produces a quantitative score of safety, which corresponds to a qualitative band (“best”, “good”, “fair”, and “poor”).

In the original test, to calculate the overall safety rating of a cookstove, each of the qualitative bands would be converted to a numerical score, This would then be summed to provide a value that matched an overall banding for best, good, fair, and poor (Johnson, 2005). However, since the protocol was created, the process for generating an overall score has been adjusted. Each test is now weighted based on the hazards that could result in greater harm (Johnson and Bryden, 2015). For instance, the test for “flames or burning fuels exiting the fuel chamber” has been given the highest weighting of each of the tests, as an injury caused by excess flames may result in severe burns and property loss. The addition of a weighting system to determine the overall safety of a stove ensures that greater significance is placed on the tests that assess for the more life threatening hazards (Johnson and Bryden, 2015).

While the protocol outlines a good starting point for a standardised risk assessment of cookstoves in the field, it appears that the protocol itself has not been critically evaluated. There is a concern that as the IWA is used as a means to levy funding for present and future stove programmes, the protocols administered to rate stoves into the framework need to demonstrate a sufficient level of reliability and validity. Therefore, the aim of this study was to determine whether the BSSP will produce repeatable scores for a cookstove if carried out by different testers.

2. Materials and methods

2.1. Methods

To test the replicability of the BSSP, the investigation brought together a number of “testers” from a range of technical backgrounds to assess the safety of five different ICS designs currently in circulation across East and Southern Africa.

2.2. Selection of testers

The BSSP was designed to be a simple method for designers and manufacturers to test stoves, in the field, without the need of complex or expensive testing equipment which cannot accessed easily in developing countries. To ensure the protocol was suitable for both international and local manufacturers, the guidance was designed to be understood by people who have different levels of technical experience and knowledge. As such, six testers for this experiment were purposively selected to represent a variety of different skill levels, exposure to ICS technology, and awareness of the risk assessment. All testers were based at a University in the UK and had a good level of written and verbal English.

2.3. Cookstove selection

To effectively assess the reliability of the protocol, it was important that the cookstoves tested represented the range of design materials (metallic and non-metallic) and fuels (wood, charcoal, and bio-ethanol). Table 1 provides an overview of the stoves selected for testing.

2.4. Testing procedure and materials

Each tester was given a copy of the safety evaluation protocol to record the scores for each stove. No additional written or verbal guidance was provided to the testers. Each tester carried out the assessment individually, at different times, so conferring was not possible. The first author was present at each of the tests for the purpose of observation *only*. They remained strictly independent of the testers and did not advise or assist during any of the ten assessments.

Testing was carried out in a combustion chamber laboratory at The University of Nottingham. Although the laboratory based setting is not true to the typical household setting in which an ICS are designed to be used, it was deemed appropriate for these assessments to provide a consistent environment for each of the testers. It was considered that although an outdoor setting may provide a more true-to-life setting. The impact of extenuating variables (weather, damp etc.) may also influence the test scores. Therefore, to ensure that minimal outside effects were present the test environment was controlled.

The equipment provided was also kept consistent. For instance, fuel provided to light the stoves were obtained from the same source. The clay and rocket cookstoves used wood from the same bag, and the Jikokoa and Zambia used charcoal from the same bag. This was to reduce variability due to differences in fuel, as it has been found that fuel moisture levels can have a significant effect on cookstove performance (L'orange et al., 2012). Although the environment was kept consistent, the order in which the stoves were assessed by each tester was random.

Once the tester had completed the assessment for each of the stoves, they were provided with a self-completion questionnaire. The questionnaire was designed to gather opinions on the simplicity, difficulty, and risks associated with undertaking protocol. Additional questions prompted the testers to consider the benefits or limitations of the guidance and, if possible, provide suggestions on how this might be improved. The questionnaire was sent electronically to each participant to complete and returned via e-mail.

2.4.1. Data analysis

The results were analysed in two parts; initially, the quantitative test data were analysed for both the individual tests and overall scores in order to identify which tests demonstrated the greatest variability across testers. The qualitative data analysis from the self-completion questionnaires was compared alongside each of the individual and overall test guidance to explore the benefits and limitations of the BSSP.

2.4.2. Ethical considerations

As the study involved human participants, the protocol was independently reviewed by the University of Nottingham, Faculty of Engineering Research Ethics Committee; ethical approval was obtained from the committee prior to undertaking the research. A risk assessment was also carried out to ensure the safety of the testers. Before agreeing to take part, participants were given a copy of the risk assessment and a participant consent form. Once consent was obtained, participants were allocated individual time slots to