Studies on Issues in Biomass Cookstove Testing

Abstract

Most traditional biomass cookstoves have very low thermal efficiency and are highly polluting, posing serious health hazards. Over the years, development of improved cookstoves in various parts of the world has focused on increase of efficiency and reduction of emissions. Several cookstove testing protocols are in use in various parts of the world, particularly for laboratory level testing. Recently, an International Standard Protocol has also been evolved. Development of such protocols has always faced two contrasting requirements: (i) repeatability of results in the laboratory (ii) accounting for the deviation between laboratory and field conditions. The present work is an attempt at recommending a protocol that can address these conflicting requirements effectively.

The experimental work has been carried out in three phases. The first phase comprises of preliminary laboratory tests for determining whether variation in fire power levels and shape of the vessel has any significant role in the performance of the stove. In phase two, systematic water heating experiments have been carried out in three sub-phases with Central Composite Design methodology used for design of experiments. Phase 2A involves variation in fuel feeding interval and fuel size at different fire power levels. In Phase 2B, experiments have been carried out on different vessel sizes, two vessel shapes at different fire power levels. In Phase 2C, effect of fuel moisture content has been determined at different fire power levels. These experiments have been carried out on two improved cookstoves – a fan-assisted improved biomass cookstove and a front feeding natural draft biomass cookstove. The third phase of experiments consists of two sub-phases: Phase 3A involving cooking experiments cum observations in the field; Phase 3B involving cooking experiments in the laboratory.

In the present study, measurements were also carried out in the field, during the actual cooking carried out by the households, and the same cooking tasks were repeated in the laboratory to understand and quantify the deviations between the results of testing protocols and field measurements. The major factors for this deviation were identified to be variation in fire power during actual cooking, cooking temperature, vessel size, shape and extent of its filling during actual cooking, which can be very different from those used in laboratory water heating/boiling tests. The above factors will show a difference between performance during water heating tests and that during various cooking tasks even in an indoor environment. The effect of winds during outdoor cooking can cause considerable deviation from indoor cooking as well and hence large deviation from water heating tests in the laboratory.

To bridge the gap between the laboratory level water heating tests and the indoor cooking experiments, mathematical models have been developed for (i) heat transfer to the cookstove body and (ii) heat transfer to the vessel. The model can be used to apply corrections for the deviations of cooking experiments from the standardized water heating tests. This would help us in predicting the thermal efficiency of cooking tasks and cooking cycles, on the basis of the water heating experiments on the same cookstove. This can be done by superimposing the thermal efficiency data of water heating experiments on the output power profiles of various cooking tasks that constitute a cooking cycle. Using these models, thermal efficiency of a cookstove, when it is used to perform cooking tasks in the laboratory or indoor kitchens, have been predicted. The predictions of the models are compared with laboratory experimental data and the agreement is found to be good, validating the models. However, in order to predict the cooking efficiency in outdoor kitchens in the field, a reliable way of accounting for the effect of wind currents needs to be evolved. This aspect has not been addressed in the present work.

A new cookstove testing protocol is proposed, in which, water heating tests are recommended to be performed over multiple fire power levels of operation of the cookstove, and use these results in conjunction with the output power – time curves of various cooking tasks, and the mathematical model described above, to predict the thermal efficiency of the cookstove for the cooking tasks. The recommended methodology has been demonstrated for three cooking tasks performed in the laboratory with the field measurements of output power – time profiles for these tasks. The predictions of the methodology agree very well with the measured thermal efficiencies of the laboratory cooking tests. A variant of the protocol is also proposed for use by the cookstove developers / manufacturers, which can help them in drawing up the specifications of any new cookstove developed / manufactured.