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COMPARATIVE STUDY OF EFFECT OF DIFFERENT PARAMETERS ON PERFORMANCE AND EMISSION OF BIOMASS COOK STOVES

ARVIND KUMAR[1], MANOHAR PRASAD[2] & K P MISHRA[3]

[1,2]Indian Institute of Technology Kanpur, Uttar Pradesh, India

[3]MGCG University Chitracoot, Madhya Pradesh, India

ABSTRACT

The effect of different parameters on performance and emission of four biomass fired cook stoves have been investigated. The parameters considered were moisture content of fuels, size of fuel, method of ignition and design, while the selected cook stoves were an traditional cook stoves, improved cook stoves developed by MNES National Programme on Improved Cook stoves(NPIC), improved cook stove developed by Thai and improved stove developed by Fiji. It was found that increase in fuel moisture content resulted in decrease in stove efficiency. The fuel size did not show any significant influence on the efficiency of the stove. The method of ignition did not affect the efficiency of the stove and it showed significant influence on design of cook stove. In this paper an attempt has been made to compare the performance and emission factors of most commonly used stove categories are presented. In this paper an attempt has been made to review energy efficiency measures of cooking stoves.

KEYWORDS: Traditional Cooking Stoves, Stove Efficiency, Moisture Content, Fuel Size, Improved Cooking Stoves

INTRODUCTION

Energy is a vital input for economic development. In most of the developing countries, wood and other biomass fuels are still the primary source of energy for majority of the people, particularly the poor. Today many people cook on slow, inefficient a traditional wood stove that causes health problems. The merit of improved chulha over the traditional is utilization of wood/biomass more efficiently, thus saving fuel wood, another main drawback of traditional stove design. Even though traditional small scale combustion of biomass degrades air quality and is thermally in efficient, the high price of cleaner substitutes and their availability in many locations make rapid shifts away from the use of the traditional fuels unlikely. Thus biomass fuels are likely to continue to meet the cooking energy needs of a majority of people in poorer countries.

In order to overcome the two major draw backs of traditional stoves, namelylow efficiency and indoor air pollution, a large number of improved fuel wood/biomass fired cook stoves have been developed in different countries. However besides improvement in design, it is also important to understand how operation of stoves influences its performance in terms of efficiency and emission of pollutants; no serious work on this appears to have been reported in open literature. This paper presents the results of a study on effect of a number of parameters of four selected stoves.

EXPERIMENTAL PROCEDURE

Cook Stoves

The wood/ biomass cook stoves used in this study are traditional cook stove and improved cook stove developed by MNES, improved cook stove(Thai) developed by Thailand, improved cook stove developed by Fiji and improves cook stove by Vietnamese.

Traditional Cooking Stove

Many rural households use traditional cooking stoves (often only a hole in the ground) that use firewood, agro residues and cow dung as fuel. These stoves have certain inherent defects: they are less than 10 percent efficient.

The produced smoke stays in the kitchen due to absence of vent pipe and ill ventilation, which is harmful to the health of users and their families:

- The open fire results in risk of accidents with children burn and/or household fire; the stove needs regular blowing

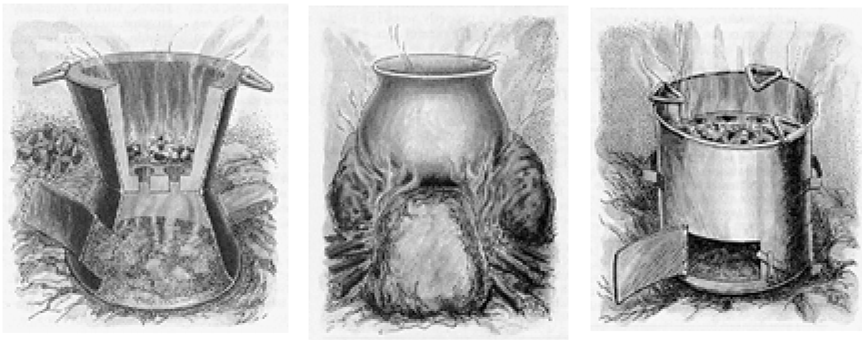

Figure 1

Improved Cook Stove Developed by MNES

A modified version of the traditional cooking stove is the Improved Cook Stove (ICS). Certain features have been modified to make them more efficient with respect to fuel wood consumption, make them convenient for cooking and much safer from a health point of view.The number of improved cook stoves has been developed by various research groups under National Programme on Improved Cook stoves in 1983depending up on the requirement

Figure 2

The above stoves are gaining popularity and a number of manufacturers are making it. For example Indian Harsha Stove is a portable, metallic, single pot stove without chimney and was designed for multi-fuel operation. Besides fuel wood, the Harsha can be used with dung cakes and a variety of agri-residues or with various combinations. The model, with a corrugated grate design with scraper (for periodical ash removal), can be manufactured by small shops having facilities for welding, cutting and punching sheet metal up to a thickness of 3 mm. This stove is gaining popularity and a number of manufacturers are making it. The stove is equipped with a well-designed fixed metallic grate with a movable ash-removing rake which can move along the space in between the grates. The stove is rectangular in shape with a metallic base with secondary air holes surrounding the combustion chamber. It has an 18-cm diameter pothole. The stove can burn wood, charcoal or coal as fuel and refueling can be done through an opening on one side of the stove.

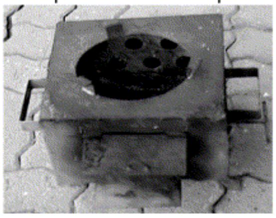

Figure 3

Thai Improved Cook Stove

The stove is made of plaster with top outside diameter of 30cm and height is 26 cm. The design of stove having a conical rim, slanted pot rests that can accommodate various sizes of pots from 16-32 cm in diameter.

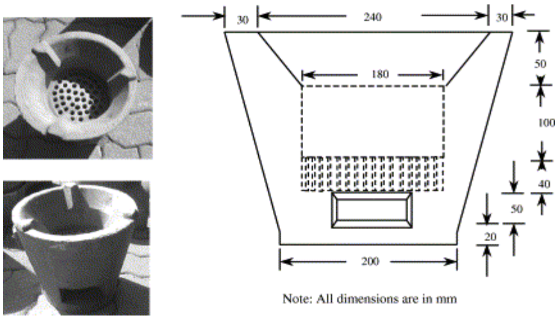

Figure 4

Fiji Improved Cook Stove

The stove designed by Fiji ministry of energy is a modification of the Indian (Hyderabad) Chula and is constructed mainly from concrete moulding.

Figure 5

Vietnam Improved Cook Stove

The stove is made of cement plaster and cylindrical in shape with a top outside diameter of 28 cm and can accommodate one pot of diameter 18-32 cm. It can burn wood, charcoal and has a metallic grate.

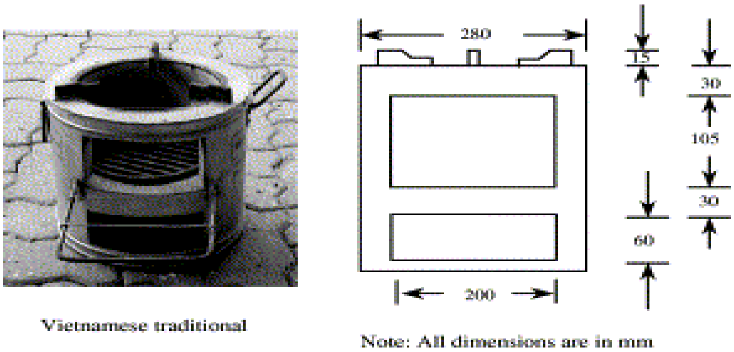

Figure 6

Efficiency Test

Efficiency is defined as the ratio of the energy entering the pot to the energy content of the fuel consumed. The energy entering the pot produces two measurable effects: raising the temperature of the water to boiling point and evaporating water. In this experiment, the water temperature was measured using a digital thermocouple.

Efficiency was determined by carrying the standard water boiling test (WBT). In the standard WBT, a known quantity of water is heated on the stove. The quantity of water evaporated after complete burning of fuel is determined to calculate the efficiency by using the following formula:

$$\eta = \frac{m_{wi}C_{pw}(T_e - T_i) + m_{i,evap}H_l}{m_f H_f},$$

where $m_{w,i}$ is the mass of water initially in cooking vessel, kg;c_{pw} the specific heat of water, $kJkg^{-1}\ K^{-1}$; $m_{w,evap}$ the mass of water evaporated, kg; m_f the mass of fuel burned, kg; T_e the temperature of boiling water, K; T_i the initial temperature of water in pot, K; H_l the latent heat of vaporization of water at 373 K, $kJkg^{-1}$; and H_f the calorific value of fuel, $kJkg^{-1}$ (higher heating value).

Emission Test

In this study, the hood method was used for testing emission from biomass-fired stoves. The stove to be tested was placed under an extraction hood through which the flue gas was sucked by using a suction blower. Since high extraction rate may influence the combustion characteristics of the stove, extraction was chosen to be strong enough to avoid flue gas to escape from the bottom of the hood but not strong enough to have any effect on the combustion flame. The hood is provided with a probe for NO_x and hydrocarbon measurements. The sample gas passes through the probe into a heated sample line and then enters a pre-filter. The outlet from the pre-filter is connected to a Y-shaped heated line which is used to pass the sample gas to two separate heated analyzers; the Signal Model 4000 VM NO_x analyzer and the Signal Model 3000M hydrocarbon analyzer.

Fuel

Wood and charcoal were used as fuel in this study. The ultimate and proximate analysis of wood and charcoal are given in

Table 1: Ultimate and Proximate Analysis of Fuel Used

Sl. No	% Ultimate	Wood	Charcoal
1	Carbon	51.5	71.4
2	Hydrogen	7.32	3.38
3	Oxygen	39.01	22.18
Sl. No	**% proximate**	**Wood**	**Charcoal**
1	Moisture	9.40	7.70
2	Volatile	70.60	20.30
3	Fixed carbon	17.20	69.65
4	Ash	2.8	3.35

RESULTS AND DISCUSSIONS

Effects of Moisture Content

The effects of moisture content of wood on efficiency and emission of the stoves were investigated. In this study, the different levels of moisture content of the fuel were obtained by adding calculated quantities of water to the fuel and. moisture content of the fuel was measured prior to testing.

To establish the effects of moisture content on the performance and emission of the stoves, each stove was tested a number of times for each level of moisture content of the fuel table 2 shows the efficiencies and emission factors of pollutants of the biomass-fired stoves at different fuel moisture content.

Table 2: Efficiencies and Emission Factors of Stoves for Different Levels of Moisture Content of Fuel

Cook Stoves	Efficiency%	Moisture%	CO	CO2	NOx
Traditional cook stove	8.5/10	27.5/24.5	42.3/52	1584.3/1565.4	0.2/0.07
Improved cook stove	9.78/24.5	26.1/19.6	40.1/78.2	1597.3/1565.5	0.19/0.12
Thai cook stove	9.8/24.5	17.1/14.5	19.7/55.8	1605.3/1572.1	0.11/0.08
Fiji cook stove	9.73/23.5	26.4/19.8	40.6/78.4	1595.3/1566	0.197/.103

The results showed that the efficiencies of all the five stoves decreased with increase in fuel moisture content. The decrease in efficiency is probably due to the fact that at higher moisture content of the fuel, a higher fraction of the heat released from combustion of the dry biomass is used for evaporating the moisture content; higher moisture content also reduces the flame temperature and thus, the rate of heat transfer to the pot. With increase in fuel moisture content from approximately 10–25%, the efficiencies reduced from 27.5 % to 24.5 of traditional stove, 26.1% to 19.6% improved stove of India from 17.1% to 14.5% of Thai cook stove, from 26.4% to 19.8% of Fiji and from 17.5% to 14.0%, on Vietnam respectively.

The emissions of CO, CO_2 were also investigated at different moisture content. As shown in table with increase in moisture content, all the five stoves showed an increase in the emission factor of CO and decrease in the emission factor of NO_x; a slight decrease in CO_2 emission factor was also observed, while, the increase in CO emission factor appears to be due to lowering of gas phase reaction (oxidation) rates at reduced temperatures caused by higher moisture content, while the decrease in CO_2 emission factor is due to the fact that dry biomass per kg of the fuel is less at higher values of moisture content. The lower value of the emission factor of NO_x is due to lower flame temperature at higher moisture content. Since the efficiency of the stoves decreased with increase in moisture content, change in emission of the different gases per unit of useful energy delivered to the pot was greater compared with changed in emission per kg of fuel. This is illustrated in figure which shows the variation of the emission factor of CO per useful MJ against moisture content of the fuel.

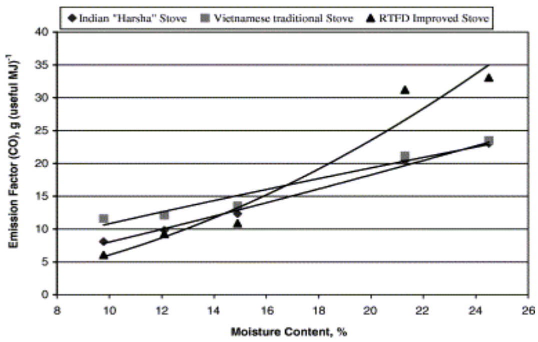

Figure 7: Emission Factor and Efficiency of Stoves at Different Wood Moisture Content (Curve Fitted)

Effects of Fuel Size

The effects of the size of wood fuel on efficiency and emission of the stoves was investigated. the fuel size had no significant influence on the efficiency of the stove.. It was observed that burn rate (kgh^{-1}) increased as the size of fuel decreased. Burn rate can be regarded as comparable to firepower (kW) It has been reported that with increasing firepower, generally stove efficiency tends to reduce, as more energy is lost to the surroundings rather than transferred to the pot] However, all the five stoves tested in this study showed no significant changes in efficiency as burn rates changed with fuel size.

The size of wood blocks seems to influence the emission of CO for the range investigated. The CO emission factor was found to reduce as the fuel size was reduced. The decreasing trend of emission factor of CO can be attributed to intensification of the combustion process, as indicated by increased burn rate, when fuel sizes are reduced; the resulting rise in temperature level inside the stove promotes complete combustion so that fewer amounts of products of incomplete combustion are produced. The different sizes of fuel did not show any significant influence on the emissions of CO_2, while there was a slight increase in NO_x emission as fuel sizes were reduced; the increase in NO_x emission can be attributed to the intensification of the combustion process for lower fuel sizes shows the influence of the different sizes of wood fuel on emission of the stoves tested.

Effects of Pot Size

The effects of the different pot sizes on the efficiency of the stoves were investigated with parameters such as moisture content, fuel size and method of ignition held constant during the test. The size of the pot did not influence the efficiency of the stoves tested. As shown in the efficiency values remained nearly unaffected when the size of the pot was varied. Although the larger pots have more heat absorbing surface at the bottom and the sidewall, this seems to be offset by the greater heat loss by the larger pot than the smaller ones due to a larger surface exposed to the surroundings

CONCLUSIONS

The effects of different parameters on performance and emissions of five biomass-fired stoves have been investigated. Parameters such as moisture content of fuel, size of fuel, size of pot and method of ignition were examined using an traditional cook stove, improved Indian stove, aThai improve cook stove, a Fiji improved cook stove and an improved stove developed by Vietnam..

In general, efficiency of the stoves decreased with increase in moisture content of fuel. Increase in moisture content of the fuel also resulted in increase in the emission factor of CO and decrease in the emission factor of NO_x; a slight decrease in CO_2 emission factor Fuel size did not show any significant influence on the stove efficiency. At lower fuel size, the emission of CO was found to decrease slightly, while that of NO_x increased slightly. The size of pan did not affect the efficiency of the stoves tested

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