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Review

Emission reduction potentials of improved cookstoves and their issues in adoption: An Indian outlook

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ABSTRACT

Biomass as a fuel for cooking is a common practice in rural India, and about 700 million people use traditional stoves to meet their energy demand. However, the thermal and the combustion efficiencies of these stoves are very low, leading to an inefficient use of biomass, and also, resulting in significant indoor air pollution. Research development has however led to the development of some improved stoves viz., natural draft and forced draft for both domestic as well as large scale cooking applications and government is trying to promote them. Forced draft stoves using processed biomass fuels (pellets) have received more prominence due to their superior performance, however, higher initial cost and limited fuel distribution networks have remained the key challenges. Improved natural draft stoves too have gained attention for being relatively inexpensive, and they are more likely to hit the rural households. In this paper, we have examined the environmental benefits obtained by the use of improved stoves for two important scenarios: traditional stoves are replaced by (i)improved natural draft stoves and, (ii) by improved natural draft as well as forced draft stoves. In the best case scenario (case ii), i.e., by shifting 111 million households who currently use wood to the forced draft stoves, and another 45 million households who are dependent on dung cake and agro residues to the improved natural draft stoves, the emission reduction that can be achieved are as follows: particulate matter (PM) 875 kT, black carbon (BC) 229 kT, organic carbon (OC) 525 kT, methane (CH_4)1178 kT and non methane hydrocarbon (NMHC) of 564 kT. With the promotion of only natural draft improved stoves, the total reductions would be ~12% lower than the combinational promotion. The CO_2 equivalent reduction is estimated to be ~70–80 MT per year.

Contents

1. Introduction

In the developing countries, the choice of cooking fuel varies

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List of abbreviations

LPG	Liquefied Petroleum Gas
IC	Improved cookstoves
NPIC	National Programme on Improved Chulhas
MNRE	Ministry of New and Renewable Energy
NBCI	National Biomass Cookstove Initiative
CO	Carbon monoxide
PM	Particulate matter
WHO	World Health Organization
BC	Black carbon
OC	Organic carbon
NMHC	Non methane hydrocarbon
BIS	Bureau of Indian Standards
GHG	Greenhouse gas

significantly in the urban and rural areas, and income and accessibility are the two main factors that govern the variations (Pohekar et al., 2005). Urban locales are dependent mainly on the cleaner fuels like LPG (Liquefied Petroleum Gas), kerosene or electricity, while the rural community are heavily dependent on biomass (Sharma et al., 2009). In India, about 90% of the rural population do not have access to the modern fuels, and the annual biomass consumption for cooking is as high as 150 million tonne (MT) (Dutta et al., 2007). Higher biomass consumption has however been a serious concern, for it involves massive deforestation (Mahapatra and Mitchell, 1999). Government has been working on various policies, and ample emphasis is given to the development of improved cookstoves (IC). Recently, petroleum ministry had conducted a wide outreach programme, and the financially sound LPG consumers are requested to surrender their subsidy for the benefits of poor. The fund generated is planned to be used in various rural schemes and as of March 2016, a sum of Rs 4166 Crore (41.66 billion) was collected from about 8.2 million families (dynamitenews, 2017). Further, for the promotion of biomass stoves, some special programmes are designed by the Ministry of New and Renewable Energy (MNRE). In early 1980s, a programme named “National Programme on Improved Chulhas (NPIC)” was launched by the Department of Non-Conventional Energy Sources. It aimed to provide quality life to women by reducing drudgery and saving fuel through improved efficiency (Hanbar and Karve, 2002). About 60 new designs were reported to evolve as a result of the research and development (R&D) activities. Government had planned for their dissemination and about 35 million stoves were distributed. However, the adoption rates were seemingly low, and ultimately the programme had to be discontinued.

Post NPIC, several researchers have critically analyzed the causes of its failure (Kishore and Ramana, 2002; Khandelwal et al., 2017; Aggarwal and Chandel, 2004). Government has also taken a rigorous exercise in analysing the situation, and in the year 2009, Ministry of New and Renewable Energy (MNRE) has launched a new programme named “National Biomass Cookstove Initiative (NBCI)” (National Biomass Cookstoves Programme). This programme emphasizes on the development of clean and efficient cookstoves, unlike the mandate of NPIC whose sole focus was on efficiency improvement. The average thermal efficiencies of the stoves developed during the NPIC were ~25% (nearly double than that of the traditional stoves) (Indian improved cookstoves, 1993). It is to be stated that though the improved chulhas developed during the NPIC period exhibited higher thermal efficiencies, however, the emission performances of all the stoves were not very impressive. Carbon monoxide (CO) and particulate matter (PM) emissions were higher than the prescribed limit of the World Health Organization (WHO) (Smith et al., 2007).

According to the WHO, the annual mortality rate from the domestic solid fuel burning in India is about 3.5 million. And due to the larger time spent in the indoor environment, women and children are the main victims (Smith, 2000). They suffer from chronic obstructive pulmonary disease, asthma, cataract, etc., and linked to the incomplete combustion of fuel. Inappropriate designs of the stoves are to be blamed for increased emissions of greenhouse gases (GHG) and PM. Traditional cookstoves are the largest sources of black carbon (BC) responsible for global warming. In the recent times, developments of ICs have been largely emphasized for the protection of climate and health. Recently, MNRE has certified ~25 new designs (Approved Models of Portable Improved Biomass Cookstoves). Two kinds of ICs are reported: natural draft combustion/gasification, and forced draft gasification type. The thermal performance of the latter category is close to the kerosene stoves and its emission characteristics can be compared to LPG. Natural draft stoves exhibit varied performance depending upon the method of air supply and the combustion intensity (Mukunda et al., 2010). Generally, the gasifier types offer better performance over the combustion stoves due to the controlled combustion process owing to the limited air supply. However, design of the air duct largely influences the performance. In comparison to the traditional stoves, the performance of the natural draft stove is however always improved. But then, unlike the gasifier stoves, the probability is there that the performance would deteriorate in the field as the designs are largely influenced by the ambient conditions (Leavey et al., 2015).

Forced draft stoves are expected to give a consistent performance while it might not be the choice of the rural poor due to its high initial cost. Currently, in India about 111 million households are dependent on fuelwood, 24 million on dung cake and 21 million on agro residues (Venkataraman et al., 2010). Assuming between 4 and 5 members per household, it amounts to about ~700 million of the total 1.20 billion, depends on biomass as a fuel for cooking. Government has targeted this population to provide better lives through the introduction of improved stoves through some structured programmes. However, the need is established but the process is too complex to meet the overall goal.

With the above background, it is essential to analyze various implementation strategies on the indoor air pollution and the fuel savings, such as the environmental benefits by promoting forced draft stoves to the middle-income group and the natural draft stoves to the poorer section. Further, it is critical to estimate the saving potential of various pollutants, when the traditional stoves replaced by the natural draft stoves. These results would provide an insight into the promotion of natural draft ICs that can reduce health impact, or if not, other strategies to be evolved to popularize the forced draft category. With Government's paramount concern over the pollution reduction, it is essential to have a critical review of the biomass stoves from the perspective of emissions unlike other studies where the historic overview, development techniques etc. were discussed (Kshirsagar and Kalamka, 2014; Sutar et al., 2015; Arora and Jain, 2016; Kumar et al., 2013).

This paper consolidates the developmental work pertaining to ICs by different researchers, and by analyzing the laboratory and field data, the emission reduction potentials of different category ICs are estimated. PM characterization being the new subject of research has not been discussed much before and this paper highlights the total BC or organic carbon (OC) emissions under different scenarios. The saving potentials are estimated for different fuel/stove combinations and the current favorable situations for India to adopt are highlighted. The issues with the ICs promotions