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Improved biomass cookstoves for sustainable development: A review

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ABSTRACT

Food is essential for survival of human being. Cooking or baking of food material requires thermal energy and such energy in developed countries is meeting through electricity. Underdeveloped or developing nations are still striving for constant supply of electricity. Biomass such as crop residues, charcoal, dung cake, etc., is the primary energy source to meet the domestic thermal energy requirement in developing nations. The biomass is available everywhere and can be burnt directly in the cookstove. It is inexpensive than other fuels and also considered as a renewable source of energy. There are numbers of initiative has taken by many government agencies to promote the energy efficient biomass cookstove to improve the fuel efficiency. This review deals with classification of cookstoves, test protocol available across the globe, global adaptation of improved cookstoves. The recent advances in cookstoves, CO_2 mitigation potential and economic assessment are also presented in this paper. The several issues concerning improved cookstoves for better adoption by user are addressed.

1. Introduction

Wood is the primary energy fuel in various thermal processes in developing countries. It is the oldest type of fuel which the man used for centuries after discovery of the fire itself [1]. In most of the developing countries, household energy demand is meeting through tradition fuels as woody biomass, agricultural waste, animal dung, and charcoal, etc. Globally three billion people still rely on such traditional fuels [2–5]. Nearly 75% of rural households in developing countries like India, still fulfill their cooking energy requirement through fuel wood in the traditional stoves [6]. Traditional method to utilize biomass for cooking is basically burning it in the open fire, sometimes enclosed by bricks or mud to act as wind shield and serves as support of the cooking vessels. Cooking in many developing countries usually carried out by burning traditional biomass using traditional stoves or three stone configuration type stoves that are very inefficient because only 5–10% of the potential energy of the biomass fuel is utilized in the cooking process and usually emit high levels of pollutants [7–9]. The World Health Organization (WHO) report reveals that the smoke released by burning of biomass contributes approximately 3% of the total global burden of disease, 1.6 million premature deaths every year, which includes 0.9 million children death under five years of age [10]. Household air pollution, inefficient energy utilization practices and unorganized fuelwood harvesting have been organized as barriers to achieve millennium development goals [11]. The adverse health outcomes are chiefly caused by inhalation of fine soot particles 2.5 micro meter in aerodynamic diameter [12]. There are many other health related issues such as asthma, lung infection, breathing problems, stinging eyes, low-birth weight and sinus problems associated with the biomass cookstoves [13]. García-Frapolli et al. [14] reported that biomass is utilized for cooking in traditional manner without considering the significant impact on health and climate change. Dissemination of technically feasible, socially reliable and economically viable improved cookstove can play vital role to reduce these impacts.

More attention is required particularly in tribal regions where population has grown rapidly, which has often resulted in local deforestation of woodlands in overspreading areas surrounding a village to fulfill their cooking fuel demands going beyond the natural re-generative capabilities of nearby forests. The immediate effects of local deforestation influence the daily life of villagers who must spend increasing amount of time and energy to collect fuelwood [15]. Traditional wood burning stoves are terribly inefficient, unsustainable, and polluting. Thus, stove technology could be significantly improved upon to reduce these negative effects by increasing efficiency through advanced combustion techniques. Cleaner and more efficient cookstoves have the potential to address the negative impacts of traditional cooking if they allow more efficient combustion of biomass fuel [16].

This review paper is written with the aim to discuss about distinctive designs of improved cookstove, testing protocols, role of cookstoves in greenhouse gas mitigation, exergy analysis, global adaptation through different implementation programme, economic assessment, and recent advancements in biomass cookstove.

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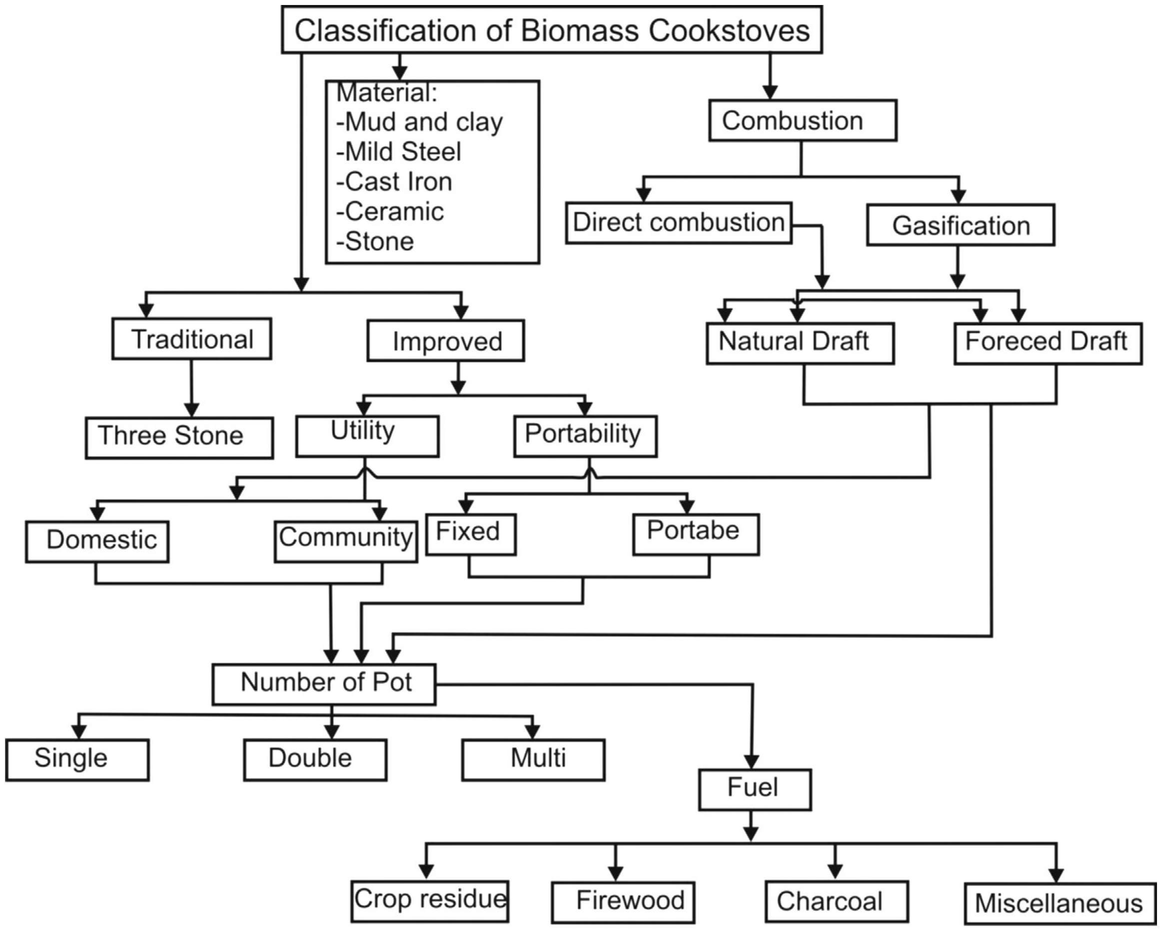

Fig. 1. Classification of biomass cookstoves.

2. Improved biomass cookstove

Improved cookstoves (ICS) are designed with the aim to get better cooking efficiency and release fewer pollutants. The improved cookstoves must meet the cooking energy demands of rural people of developing countries. It is the improved use of biomass in households which, leads to reduced fuel consumption [17]. On the other hand, use of improved cookstove reduces the fuel collection burden placed on women and children, and also saves the time. Women in free time can engage in other income generating activities and children may spare more time to get education, especially girl-child [18]. Improved cookstoves should be designed in such ways that are acceptable to the users. Firstly, the proposed improved design must be inexpensive as compared to use open fires. Secondly, the stove must be durable to withstand heavy use without cracking for at least a year and preferably longer. Then, the design should be able to be constructed with locally available resources and tools [7]. There are numbers of biomass cookstove designs are available and can be classified on the basis of their construction material, number of pot, type of fuel, etc. The classification of biomass cookstoves is depicted in Fig. 1.

3. Testing protocols adapted worldwide

There are numbers of cookstove testing protocols are used in different countries to evaluate the thermal performance of cookstove in both laboratory and field conditions. The Water Boiling Test (WBT) is one of the principal lab test protocol widely used in the different countries in different manner as presented in Table 1.

Cookstove testing protocols reveal the systematic approach to measure the advantages, limitations, and its adaptability in actual use, and it is considered as an important tool in ICS dissemination programme. Volunteers in Technical Assistance (VITA) [19] in 1985 had taken an initiative to develop an internationally acceptable standard for cookstove testing, and proposed a step by step procedure for water boiling test (WBT) which is a lab test, with actual cooking tests i.e. controlled cooking test (CCT) and kitchen performance test (KPT) that are helpful in finding real life performance of the cookstove. Subsequently, other WBT protocols were also developed by various research organizations, which are as follows:

Uganda National Bureau Standards developed a test protocol, i.e. US 761 which specifies the performance and test methods for household biomass cookstoves with different biomass fuels [20]. Further, the standard includes heat transfer test, thermal shock/stress resistance test, thermal conductivity determination for ceramic liner, safety considerations, etc. The emission measurements are not included in the developed protocol.

DB11T 540 [21] was proposed by the Quality and Technical Supervision Bureau of Beijing Municipality, China. It provides technology, manufacturing and safety requirements, test methods and inspection rules for household biomass cookstoves. This standard gave emission limits of different air pollutants.

DeFoort et al. [22] prepared Emission & Performance Test Protocol (EPTP) in collaboration with stove manufacturers (Envirofit International and Philips) and Colorado State University. The unique features of EPTP test code are the floating layer of foam insulation on top of the water in the test pot during the cold- and hot-start tests, to reduce vaporization and use of 90 °C instead of boiling the water to reduce the variation in final temperature.

Adapted Water Boiling Test (AWBT) version 2.0 [23] was proposed by the Research and Development Unit of Group of Renewable Energy,