SCREENING AND EVALUATION OF FIREWOOD SPECIES FOR SUSTAINABLE UTILIZATION AND HEALTH MANAGEMENT IN RURAL AREAS OF CHAMARAJANAGARA DISTRICT

Major Research Project Report

Submitted to

University Grant Commission (UGC)

New Delhi

Submitted by

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Mysuru- 570006

2017

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DECLARATION

I, hereby declare that the work presented in this project entitled "Screening and Evaluation of Firewood Species for Sustainable Utilization and Health Management in Rural Areas of Chamarajanagara District" has been originally carried out by me under Major Research Project [UGC-F.No.42-414/2013(SR), Dated;22 March 2013).

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Abbreviation

ARI	-	Acute Respiratory Infection
ASTRA	-	Application of Science and Technology for Rural Areas.
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
COPD	-	Chronic Obstructive Pulmonary Diseases
CV	-	Calorific Value
DSC	-	Differential Scanning Calorimeter
EDTA	-	Ethylene Diamine Tetra Acetic Acid
EIV	-	Extraction Impact Value
EPA	-	Environmental Protection Agency
ESR	-	Erythrocytes Sedimentation Rate
FVI	-	Fuel wood Value Index
GHG	-	Greenhouse Gases
Ha	-	Hectare
HAP	-	Household Air Pollution
HHV	-	Higher Heating Value
Hpf	-	High Power Field
IEA	-	International Energy Agency
ICS	-	Improved Cook stoves
IL	-	Interleukin
Kcal	-	Kilocalorie
LGA	-	Local Government Areas
LHV	-	Lower Heating Value
LPG	-	Liquid Petroleum Gas
MCV	-	Mean Corpuscular Volume
MJ	-	Mega joules
MT	-	Million Tonnes of Oil Equivalent
NDIR	-	Non-dispersive infrared spectroscopy
NFHS	-	National Family Health Survey
NIOSH	-	National Institute for Occupational Safety and Health
PAH	-	Polycyclic Aromatic Hydrocarbons
PHU	-	Percent Heat Utilization
PM	-	Particulate Matter
RBC	-	Red Blood Cells
SPM	-	Suspended Particulate Matter
TCS	-	Traditional Cook stoves
TERI	-	The Energy and Resources Institute
TNF	-	Tumor Necrosis Factor
TSPM	-	Total suspended particulate Matter
WBC	-	White Blood Cells
WHO	-	World Health Organization

1. INTRODUCTION

Energy plays a vital role in a nation's economic growth, progress and development. It is vital for socio-economic and human development as well as for poverty eradication (Eleri *et al*., 2012; Oyedepo, 2012). The growing demand for and depleting trend of fossils fuels are major drive towards the threat on energy security and economic growth (Nhuchhen and Salam, 2012).

Energy is essential to life and facilitates all human endeavour. It is the life-blood of industry and the vital factor in domestic comfort, like heating and cooling, illumination, health, food, and education (Hartley, 1984). Energy is also a vital commodity in transportation. Energy shapes the development of human society and civilization. Energy is considered as a prime agent in the generation of wealth and also a significant factor in economic development (Demirbas, 2003).

Energy contributes to widening opportunities and empowering people to exercise choices. Access to energy is essential for economic, social and political development. Changes in the way energy is produced and use can be instrumental in socio-economic development, poverty alleviation, and social change, as well as in improving the living conditions of women (Goldemberg and Johansson, 1995). It encourages individual development via an improvement in educational and sanitary conditions (Kauffmann, 2005). Conversely, its absence can constrain both men and women from contributing to economic growth and overall development.

Developing countries often face constraints to growth and development that are directly related to the un-sustainability of current patterns of energy production and use. At present, energy use patterns are skewed towards conventional energy sources, which not only hamper economic growth and conservation of the environment, but also aggravate social and gender inequities (Shailaja, 2000). The shortage of energy in rural areas has made people living in these areas to become trapped in subsistence level economies characterized by inefficient use of non-commercial energy, low agricultural productivity and poor standards of living (Best, 1992).

There is a natural and universal hierarchy in the use of domestic fuel. As income increases, wood and charcoal are replaced by kerosene and butane gas or liquid petroleum gas (LPG), which are in turn replaced by natural gas or electricity (Alier, 1995). The highest income group of households significantly reduced biomass use (Jiang and O' neill, 2003). Jungbluth (1995), reported that when choosing between kerosene and LPG, the latter is preferable, on the basis of the environmental impacts of the entire fuel cycle (extraction of petroleum and natural gas, processing, transport, and distribution), and cooking. Cleaner fuels like LPG, kerosene, electricity and other modern fuels being a costly form of fuel are used by families in urban areas (Andrea *et al*., 2001). Kerosene is used by many rural poor households for lighting and to a limited extent, for cooking (Kebede, 2001).

The domestic demand for wood-energy is strongly related to household income. Evidently, agricultural households and irregular income households used more biomass energy than households that are business owners or have members employed in government offices and private enterprises with regular incomes (Nansior *et. al*., 2013). A multinomial logit model shows that households head's age, educational attainment, household size, type of dwelling unit, the duration of food cooked and price of fuel wood are statistically significant factors influencing household's choice of cooking fuel (Baiyegunhi and Hassan, 2014).

Use of renewable energy has received high priority in many countries in the face of the diminishing supply and increasing price of fossil fuels (REN21, 2013). Biomass is viewed as an especially promising type of renewable energy because it is widely available, can be derived from a variety of sources, can be locally produced in most rural communities, and is considered to be a type of "green" energy (Bartuska, 2006). It is a potential source of alternative energy and widely recognized in the field of economic development. However, there is considerable evidence that biomass energy continues to play an important role as a household energy source in rapidly developing countries in the Asia-Pacific region (IEA, 2012).

The number of people relying on biomass will increase to 2.7 billion by 2030 because of population growth. That is, one third of the world's population will still be relying on these fuels. There is evidence that, in areas where local prices have adjusted to recent high international energy prices, the shift to cleaner, more efficient use of energy for cooking has actually slowed and event reversed. It was estimated that over 2.5 billion people, or 52% of the population in developing countries, depend on biomass as their primary fuel for cooking. Over half of these people live in India, China and Indonesia. However, the proportion of the population relying on biomass is highest in sub-Saharan Africa. In many parts of this region, more than 90% of the rural population relied on fuel wood and charcoal. The share is smaller in China, where a large proportion of households use coal instead (WEO, 2006). Poor households in Asia and Latin America are also very dependent on fuel wood.

Biomass includes firewood, agricultural residues, cow dung, saw dust and other organic waste. It is estimated that globally, almost 3 billion people rely on biomass and coal as their primary source of domestic energy (cooking and heating) and it is expected to grow until at least 2030 (IEA, 2002; WHO, 2002). In India, biomass fuels dominate rural energy consumption patterns, accounting for 80% of total energy consumed. Fuel wood is the preferred and dominant biomass source, accounting for 54% of biomass fuels used in India. One of the important features of rural energy use is the dependence on locally available biomass resources (Swaminathan Research Foundation, 2011).

In India, biomass fuels dominate the rural energy consumption patterns, accounting for over 80% of total energy consumed (Ravindranath and Hall,1995). It meets about 75% of rural Indians energy needs, while in Karnataka, non-commercial energy sources like firewood, agricultural residues, charcoal and cow dung account for 53.2% (Ramachandra, 2007).

More than 70% of Indian population lives in rural areas and they meet out 80% of their energy needs only from fuelwood. Currently fuelwood is the major energy source for cooking. Hence, scarcity of fuelwood is well recognized. Most of villages collect fuelwood from nearby forests, which lead to deforestation (Bhattacharya, 2005). The total demand of fuelwood in Karnataka state was 19.4% million tonnes, out of which 18 million tonnes was the domestic fuel (Anon, 2002).

A recent study on energy utilization in Karnataka considering all types of energy sources and sector wise consumption reveals that, traditional fuels such as firewood (7.440 million tonnes of oil equivalent (MT)-43.62%), agro residues (1.510 MT-8.85%), and biogas and cow-dung (0.250 MT-1.47%) account for 53.20% of total energy consumption (Ramachandra *et al*., 2000).

Heavy reliance on biomass fuels in developing countries has raised global concerns over both environmental consequences such as forest degradation, soil erosion and the adverse health consequences of indoor air pollution generated by burning wood, animal dung or agricultural residues (Bruce *et al*., 2000).The impact of firewood collection on forest degradation and its relationship with rural livelihood has been largely debated, the issue receiving varying attention over time (Arnold *et al*, 2003; 2006).

The use of these biomass fuels causes considerable hardship and health hazards among rural women fold (Raiyani *et al*., 1993; Smith, 1993; Cecelski, 1995; Parikh, 1995; Parikh and Laxmi, 2000). The women in the poor families, assisted by their children, spend arduous hours every day gathering fuel, e.g., trekking ever longer distances to find and carry back heavy loads of increasingly scarce firewood and using it to prepare meals using crude stoves, the inefficiency of which aggravates the fuel-gathering task (Reddy *et al*., 2000 and Goldemberg *et al*., 1988).

Biomass is directly used for thermal energy under different biomass cook stoves. There are many types of biomass cook stove such as traditional (three stone fire), single, double and tri pot clay stoves and metal and Astra cook stove. However, burning of biomass under poorly designed cook stove contribute indoor air pollution. The concentrations of indoor air pollutants originating from the burning of solid fuels depend on a number of factors such as fuel type, housing characteristics and method of cooking. Depending on cooking activities, the extent of pollution can vary between days and within day (Ezzati *et al*., 2000; He *et al*., 2005).

Burning of biomass emits several health damaging pollutants such as carbon monoxide, sulfur dioxide, nitrogen oxides, carbon dioxide, benzene, PAH and suspended particulate matter etc. These pollutants cause acute respiratory infections, chronic obstructive pulmonary disease, asthma, nasopharyngeal and laryngeal cancer, tuberculosis and diseases of the eye (Andrae and Merlet, 2001) in human beings. Low birth weight in children and cardiovascular diseases are also associated with indoor air pollution.

A great deal of attention has focused on particulate matter (PM) pollution due to their severe health effects, especially fine particles. Several epidemiological studies have indicated a strong association between elevated concentrations of inhalable particles (PM_{10} and $PM_{2.5}$) and increased mortality and morbidity (Perez and Reyes, 2002; Lin and Lee, 2004; Namdeo and Bell, 2005).

The most common indicator of fine particulate matter is $PM_{2.5}$, consisting of particles with an aerodynamic diameter less than or equal to a 2.5 µm. Ultrafine particles are typically defined as particles with an aerodynamic diameter <0.1 µm (Oberdorster *et al*., 2005). With regard to $PM_{2.5}$, various toxicological and physiological considerations suggest that fine particles may play the largest role in effecting human health. For example, they may be more toxic because they include sulfates, nitrates, acids, metals, and particles with various chemicals adsorbed onto their surfaces. Furthermore, relative to larger particles, particles indicated by $PM_{2.5}$ can be breathed more deeply into the lungs, remain suspended for longer periods of time, penetrate more readily into indoor environments, and are transported over much longer distances (Wilson and Suh, 1997).

Biomass burning emissions are considered to be a significant source for public health hazard and also have a significant impact on climate change (Arbex *et. al.,* 2007). Biomass burning either in open or poorly ventilated stoves emits hundreds of health damaging pollutants and causing acute respiratory infections, chronic obstructive pulmonary disease, asthma, nasopharyngeal and laryngeal cancers, tuberculosis, and diseases of the eye (Andreae and Merlet, 2001).

It is estimated that indoor air pollution causes about 36% of lower respiratory infections and 22% of chronic respiratory disease (UNEP, 2006). A child exposed to indoor air pollution is two to three times more likely to catch pneumonia, which is one of the world's leading killers of young children. In addition, there is evidence to link indoor smoke to low birth weight, infant mortality, tuberculosis, cataracts and asthma. As well as direct effects on health, indoor air pollution worsens the suffering and shortens the lives of those with both communicable diseases such as malaria, tuberculosis and HIV/AIDS, and chronic diseases, notably cardiovascular diseases and chronic respiratory diseases, which are by far the world's worst killers. Four out of five deaths due to chronic diseases are in low and middle income countries (WHO, 2005).

In the long run, and even today biomass risk can be reduced by using a modern cooking fuel instead of traditional one. There are many fuels that can substitute for, or supplement the use of, biomass in the household energy mix such as biogas, kerosene and LPG etc.

In view of their ability to reduce indoor air pollution levels substantially and their short-term potential for expansion, a number of fuels are well placed to make major contributions to improving the household energy situation in developing countries. LPG is already quite well established in some countries.

Biogas has considerable potential in many rural communities, though the capital costs are directly comparable to those of liquid fuels.

It is reported that the ASTRA improved stove had the highest PHU (Percent heat utilization-34%), considerably higher than the traditional stove fuelled with firewood (14.2%) (Ravindranath, 1997). The concentrations of aerosol components and gases in the indoor air during the operation of improved cooking stoves (ICS) were found to be lower as compared to traditional cooking stoves (TCS) (Singh *et al*., 2014). The choice of cook stove plays an important role in reduction of biomass smoke related health hazards.

The impacts of biomass burning can also be minimized by adopting new technologies for example properly designed cook stove to eliminate biomass smoke emissions. The replacement of biomass cook stove with clean biomass cook stove helps in sustainable utilization of biomass energy for better health. Although biomass used with traditional stoves can be carbon neutral (if CO_2 emissions from the combustion process are offset by absorption during regrowth), the process is not emissions-neutral unless the biomass fuel is burnt efficiently and completely (UNEP, 2006). Although the overall impact on emissions of switching to modern fuels can be either positive or negative, improved stoves and greater conversion efficiency would result in unambiguous emissions reductions from all fuels.

However, switching away from to traditional fuels to commercial fuels involves capital expenditure for the stove and recurring expenditure for the fuel itself. Many poor households would not be able to afford the required capital investments. The cost of buying a stove and paying money for a fuel represents a serious barrier for many households. In this regard government should give an attention and take an action to provide efficient cooking fuel and to meet the cooking fuel target.

There are many ways in which policy makers and other stakeholders can help to make clean fuels affordable. Government could facilitate commercialization of LPG by designing financial incentives, setting technical standards and extending credit facilities to stove-makers and proving marketing support. These would lower the initial deposit costs, encouraging more regular LPG consumption, especially in rural areas. In addition this, Government should provide subsidies and incentives to the rural households to buy improved cook stoves as well as efficient cooking fuels. This type of programme will assist households in choosing modern, more convenient fuels without cost of being a barrier to uptake. Governments can also support cleaner cooking by developing national data bases which include information on potential fuels, stoves, the infrastructure and potential providers, together with cost analysis and estimates of the ability to pay, as a function of income.

Scope of the study

1. Assessment of available bio resources is helpful in revealing its status and helps in taking conservation measures and ensures a sustained supply to meet the energy demand in the rural areas.
2. Based on the results of the investigation suitable biomass energy utilization which cause no or minimum health hazard will be recommended. Such species can grow in waste land of villages.
3. The present energy consumption patterns provide basic knowledge for designing forest management plans to meet immediate and long-term energy needs in rural areas.
4. This in turn helps in minimizing the exploitation of natural forests and their conservation.

2. REVIEW OF LITERATURE

Biomass energy and utilization pattern

One of the important features of rural energy is the dependence on locally available biomass resources. Use of biomass is not in itself a cause for concern. However, when resources are harvested unsustainably and energy conversion technologies are inefficient, there are serious adverse consequences for health, the environment, and economic development.

Biomass use in rural areas continues to increase. An increased dependence on fuelwood in rural areas has been indicated with the share of fuel wood in cooking increasing from 56% in 1989/1990 to nearly 62% in 1994/1995(TERI 2001-2002). According to Jiang and O'Neill (2003), biomass was still used by about two thirds of rural households and accounted for 60 to 70% of total energy use in rural China at the end of the 1990's.

Fire wood (defined here as solid wood, mainly from the tree trunk) is society's oldest source of household energy and is still used around the globe (FAO, 2005), even in technologically advanced countries with high energy consumption (Warsco, 1994; Roser *et al.*, 2003).

In rural areas the dependence on bio energy to meet the domestic requirements such as cooking and water heating purposes is as high as 80-85%. Fuel wood and agricultural residues are also widely used as fuel in rural industries such as cashew processing and other agro processing industries, brick kilns, and in commercial sectors such as hotels etc. Investigations of energy consumption in few selected villages of Kolar taluk revealed that per capita fuel wood consumption for domestic purposes such as cooking, water heating etc., are in the range 1.3 to 2.5 kg/person/day (Dabrase *et al*., 1997).

Fuel wood is the most commonly used and is the staple energy source of the 75% of the population of the developing countries (Desai, 1991). Rural areas account for about 85% of the total fuel wood consumption (Anon, 1988). It is the major energy source for the rural people and it fulfills about 68% of the total energy demand (Maheswari *et al*., 1997). A large portion of the rural energy demand is met from the locally available fuel wood, cow dung and agricultural residues (Natarajan, 1997). The fuel wood requirements for domestic purposes in rural areas are enormous (Rai and Chakrabarti, 2001).

Joshi *et al*., (1992) study confirms the predominance of firewood use in rural areas with analysis indicating the 95% confidence interval for per capita consumption (national aggregates) for cooking in the range of 1.10-1.34 kg/capita/day. The consumption of dung cake was lower with 95% confidence interval of the per capita consumption showing 0.40-0.49 kg/capita/day. The agricultural residue consumption was marginally higher with 95% confidence interval range of 0.47-0.63 kg/capita/day.

In many of the developing countries, forests are the main source of fuel wood, timber for house construction and fodder for livestock. Consequently, any depletion of this resources base can erode living standards as well as ecosystem stability (Shah, 1982; Pant and Singh, 1987).

Ravindranath and Oakley (1995) reported that the dominant sources of fuelwood were 26% each from forests and own farms, 17% from roadside collections and other sources including neighbours' farms, and the rest purchased (NCAER, 1985). According to a National Sample Survey (NWDP, 1986), private home gardens and trees around houses contribute 30 Mt of annual fuelwood. Village forestes and degraded land are also important sources of woody biomass.

For community managed production, the types and existing sources of woody biomass are also important factors to consider. Twigs, branches, roots, shrubs, climbers and brushwood are more important sources of woodfuel than cut logs which involve felling trees. Ravindranath and Oakley (1995) reported several such species as providing these resources in India; *Prosopis juliflora*, *Lantana camara*, *Cassia auriculata* and *Tecoma stans*. Leach (1987) has noticed that only 12% of fuelwood came from logs that involved the felling of trees, and 88% was from the cutting of branches. Ravindranath *et al*. (1992) estimated a total annual incremental standing biomass from forests in India as being 138 Mt, of which branches and twigs accounted for 42 Mt.

A study of 12 semi-arid districts of rural India showed that 66-88% of total domestic fuel needs of marginal farmers (those with <2 ha land) and the landless poor were derived from village commons, and 8-32% of large farmers also obtained their domestic fuel from village commons (Jodha, 1990). Several other studies have indicated that thin tree branches were the main type of fuel wood gathered as larger branches have a market value and are therefore sold (Ranganathan *et al*. 1993;Reddy, 1982).

Mamun *et al*., (2009) conducted a research work to assess the availability and utilization pattern of biomass and identify the appropriate biomass energy saving technologies in rural areas of Bangladesh. The common biomasses are tree twigs, leaves, firewood, crop residues, jute sticks, rice husk, rice straw, sawdust, cow dung etc. and constitute about 60% of total energy consumption in rural households. The potential biomass availability in the study areas was about 291.47 GJ/yr-household of which the share of field crop biomass was about 229.61 GJ/yr-household. He suggested that, fewer inputs than do annual row crops, and fast growing plants like *Dhaincha*, *Eucalyptus*, *Epil-Epil*, *Bogamedula*, etc. might also be cultivated for biomass production. He concluded that energy saving technologies should be encouraged for efficient use of available biomass in the country.

Mahapatra and Mitchell (1999) have examined the patterns of biomass fuel use in rural India and supply effects on household consumption. Their analyses showed that socioeconomic factors influence the bioenergy use, but scarcity of forests does not lower the demand for biofuel nor is it a driving force for farm forestry.

The availability of fuelwood significantly influences its consumption. The population centers in proximity to the forest resource have higher per capita consumption than those lying farther, as an adequate quantity of preferred fuel (wood) is available and mixing /substitution with inferior fuel (crop residue, dung cake) is not required. A study conducted in Gujarat revealed that the villages with a forest resource have almost twice the per capita consumption of fuelwood as that of villages without forests (Pinto *et al*., 1985). The rural areas having no forests compensated fuel needs by increasing the share of agricultural residues, dung cake, and kerosene.

The linkage between modern energy access and welfare is well documented. For example, the burning of biomass energy (e.g., fuel wood, dung, or crop residue) in conventional ways often contributes to indoor air pollution and is thus a health hazard (World Bank, 2002). The use of more modern fuels, such as LPG, can alleviate this problem. In rural areas, the collection of fuel wood, often performed by women and school-going children, takes time away from other productive pursuits (Saghir, 2004; Barnes and Toman, 2006). Thus, replacing traditional ways of consuming biomass with more efficient energy-consumption methods or consumption of modern energy can lead to time savings and better opportunities.

More than 1 billion of the world's females (women and their daughter) relied on 'free' solid fuels (fuel wood and dung) for cooking and heating (Goldemberg *et al*., 2004). There is linkage between the burden of carrying fuel wood over increasingly greater distances and the progressively greater dependency on dung as fuel (Eckholm, 1975; 1976).

Studies conducted by Pandey (1984), showed that in many areas of the Himalaya, and especially in Nepal, the use of dung for fuel is more closely related to the ethnic origin of the community rather than shortage of fuelwood.

Sinha and Joshi (1994) reported that the contribution of firewood has remained around 65% of the rural energy during the last three decades. The demand of fuelwood in rural sector for domestic needs in 1991 was 180 million tonnes, with the average consumption in villages being 1.22-kg/capita/day.

Sinha (1998) carried out a research work on energy use in the rural areas of India. His study revealed that the national average for domestic thermal energy consumption estimated (629 kcal or 2.63 MJ per capita daily) is much similar to the rural domestic thermal energy requirement assumed in most energy planning exercises in India in the past. His estimates indicate that at least 180 million tonnes of firewood, 40 million tonnes of dung cakes and 30 million tonnes of agricultural residues were consumed in the rural sector for meeting the domestic thermal energy requirement in 1991.

Sohel *et al*., (2010) study determines the biomass fuel consumption pattern and environmental consequences of biomass fuel usage in the traditional and improve cooking stove. The introduction of improved cooking stove minimizes people’s forest dependence by reducing the amount of fuel wood required to meet their household needs. Firewood was the most frequently used biomass fuel. It has been figured out that the incomplete combustion of biomass in the traditional cooking stove poses severe epidemiological consequences to human health and contributes to global warming. While improve cooking stove help to reduce such consequences.

Godfrey *et al*., (2010) conducted a study to examine household firewood consumption and its dynamics in Kalisizo sub-county of Rakai district, central Uganda. Fifty households were selected to determine the preferred tree/shrubspecies for firewood and the socio-economic dynamic of firewood consumption in the households. Findings indicated a very strong positive correlation (R2 = 0.919) between a household family sizes and the volume of firewood consumed per day. On average, a household with a family size of about seven persons consumed 1.56 m^3 of firewood per year. The most preferred tree and shrub species for firewood were *Sesbania sesban* (85%), *Eucalyptus* (83%), *Calliandra calothyrsus* (73%), *Ricinus communis* (68%), and *Ficus natalensis* (63%). He concluded that there is a need for continued sensitization of household members about fire management in traditional three-stone fire cooking stoves to reduce firewood consumption and waste. Studies have also, shown that efficiency of a three-stone fire cooking stoves can be quite high if the fire is closely tended and managed.

Ouedraogo (2006) investigated on household energy preferences for cooking in urban Ouagadougou Burkina Faso. His study showed that the inertial of household cooking energy preferences are due to poverty factors such as low income, poor household access to electricity for primary and secondary energy, low house standard, household size, and high frequency of cooking certain meals using wood fuel as cooking energy. The descriptive analysis of his study shows that the domestic demand for wood energy is strongly related to household income.

The energy ladder study by Leach (1992) was based on the factors that determine the choice of fuel used and both studies concluded that the choice of fuel is determined by a particular household's personal choices and income. These studies argue that fuel switching in developing countries has been that households gradually ascend in 'energy ladder'. There is a tendency for a linear progression from relatively inefficient fuel and energy end use equipment to a more efficient fuel, electricity and equipment, with increasing income levels and urbanization (Farsi *et al*., 2004). However, research into the energy consumption of households in developing countries shows that the energy ladder theory is simplistic. Because there are many factors other than income that determine fuel choice e.g. culture, social desirability and security of supply (Davis, 1998; Bernett, 2000).

Hosier and Dowd (1987) conducted a similar study in urban Zimbabwe using a multinomial logit model to test energy ladder hypothesis for household fuel choice. The multinomial logit model refers to a model, which shows that although economic factors do affect fuel choices, a large number of other factors such as culture, social desirability and security of supply are also important in determining household fuel choice. Furthermore, fuel switching is often not complete and is a gradual process with many households often using multiple fuels. There are a number of reasons for multiple fuel use and sometimes they are not dependent on economic factors alone. In some households, people choose to use more than one energy source because people want to increase the security of supply. In other cases, the choice might be dependent on cultural, social or taste preferences.

Kataki and Konwer (2001) have studied the fuel wood characteristics of four indigenous perennial species of North East. Physico-chemical parameters like moisture and ash content, density, solubility in cold water, hot water and alkali, cellulose, holocellulose, lignin and extractive contents of different parts of these species were determined. Leaf component of all the species contained the highest calorific value presumably because of the higher extractive content, followed by heartwood. The study identified *A. lucida, S. fruticosum* and *P.lanceaefolium* to have better fuel wood properties to be raised as energy plantation.

Calorific value is defined as the amount of energy released from the combustion of a unit mass of a combustible material. Calorific values of plants are important indices for evaluating and reflecting material cycle and energy conversion in forest ecosystems.

There are two kinds of calorific value; higher heating value (HHV) and the lower heating value (LHV). Different calorimeters have been used to determine gross calorific value. Harada (2001) used a cone calorimeter to determine the heat release rate and time of ignition of nine wood species. Riguerra *et al.,* (1996) used a static bomb calorimeter to determine HHV of forest wastes.

Krigstin *et al.,* (1993) used a differential scanning calorimeter (DSC) to evaluate the energy characteristics of hybrid willow. Several other studies argued that compared to conventional adiabatic oxygen calorimeter, a DSC gives more accurate measurement as it accounts for heat dissipation, incomplete combustion and heat of vaporization. However, standard methods (ASTM E870-82) recommend the use of an oxygen-bomb calorimeter to measure gross calorific values of wood. Based on these methods, calorific values of wood vary between 15 and 25 KJ/g (Harada, 2001).

Several studies have focused on evaluating the calorific value of poplar wood and its dependency on tree characteristics. For instance, for *P. deltoides* and *P.euramericana*, the HHV of age 1, 2 and 12 year old oven dry poplar was measured in the 16KJ/g to 24KJ/g range (Klasnja *et al*., 2002). Therefore, the study suggests that tree age is an important factor of HHV in hybrid poplars and wood itself is more favorable in HHV compared to bark.

Blankenhorn *et al.*, (1985) measured the HHV of seven *Populus* hybrid clones from age 1 to 8. These clones include wood, bark and wood/bark specimens that exhibited variations from 17.7 to 20 KJ/g. The study showed that the heat of combustion within and among clones was significantly different for some wood, bark and wood/bark specimens. However, no apparent trends were found in these clones with regards to their ages. Seven yellow poplar woods were also evaluated by Harris (1984) and the effect of location in the tree was determined.

The calorific values (CVs) and ash contents (ACs) of different plant organs (*Pinus massoniana*) were analyzed systematically using hypothesis test and regression analysis (Zeng *et al*., 2012). The study shows that the CVs and ACs of different plant organs are almost significantly different. The CVs and ACs of different organs are related, to some extent, to diameter, height and origin of the tree, but the influence degrees of the factors on CVs and ACs are not the same.

Gravalos *et al*., (2010) work presents an experimental study on calorific energy values of biomass residue pellets for heating purposes. The fuel samples used, were biomass residues of agricultural (cotton, cardoon, etc.) and forest (pine, fir, beech, etc.) wastes. This research is part of a continuing program to obtain precise thermal analysis data from different kinds of agricultural and forest by-products. A bomb calorimeter was used to determine the calorific values by the standard ASTM method. Their experimental results obtained are encouraging and show that these materials can be used as alternative fuels.

Bhatt (2004) has carried out his research in North-Eastern Himalayan region for quantitative analyses of 26 indigenous mountain fuelwood species to identify trees with potential for fuelwood production. A fuelwood value index (FVI) was defined as calorific value x density/ash content. Keeping this in view, a combination of three factors: calorific value, density, and ash will be most appropriate in determining the suitability of a wood as fuel. His study revealed that

Betula nitida, Machilus bombycina, Itea macrophylla, Cryptomeria japonica, Gmelina arborea, Simingtonia populnea, Macaranga denticulate and Schima wassichii were shown to have promising firewood production.

Githiomi *et al*., (2012) reported that trees on farm were found to be the major supply of the woodfuel energy where firewood was the main source of household energy followed by charcoal. Traditional three stones stoves were most commonly used by the households. Improved charcoal stoves were the second commonly used while only a very negligible percentage used kerosene stoves and gas burners. The study recommended integration of wood fuel production to local farming systems and establishment of fuelwood plantations by Kenya Forest Service to substitute on farm sources. It also recommended promotion of improved stoves with higher efficiency to reduce the wood fuel used as well as improve on environmental pollution.

Jonathan *et al*., (2009) showed that for over 80% of 6.5 million people in Papua New Guinea, fuelwood continuous to be the main source of energy. Total of 31 most preferred species from 15 families cited from 6 study sites and indicated as preferred by local users. The calorific values exhibited by these species ranged from a minimum of 13.8 to a maximum of 35.9 kJg^{-1}. Apparently, the species calorific values were affected by their biochemical and physical properties, including their age. His work also describes an investigation of factors which may affect calorific values of tree species such as age, physical and biochemical properties. Finally, the paper also advocates the merits of considering type of tree species with high calorific values during replanting fuelwood tree species in order to meet growing demand of fuelwood supply.

Kumar *et al.,* (2009), study revealed that the wood with highest calorific value does not necessarily constitute the best option as fuelwood, if elemental composition is taken into account. They suggested some species (*A.nilotica and C.fistula*) considering the calorific value and elemental factor for better plantation as fuelwood.

According to Kataki and Konwe (2001), *A. Lucid, S.Fruticorum* and *P.Lanceaefolium* have better fuelwood properties and he considered for inclusion in energy plantation programme of north-east India.

According to Thomas *et al*., (2011) firewood is the basic fuel source in rural Bolivia. A study was conducted in an Andean village of subsistence farmers to investigate human impact on wild firewood species. A total of 114 different fuel species was inventoried during fieldtrips and transect sampling. Specific data on abundance and growth height of wild firewood species were collected in thirty six transects of $50x2m^2$. Information on fuel uses of plants was obtained from 13 local Quechua key participants. To appraise the impact of fuel harvest, the extraction impact value (EIV) index was developed. Their results suggest that several (sub) woody plant species are negatively affected by firewood harvesting.

Singh *et al.,* (2010), estimated that a total of 88 species are consumed as fuelwood (54 trees and 34 shrubs) by the local people. Fuelwood consumption by ‘dabha’(roadside refreshment establishments) owners (90-120kg/household/day) was much higher over the common villagers(20-22 kg/household/day). The fuelwood is mainly burnt for cooking, water heating, space heating and lighting etc. Among these, cooking consumes the fuelwood most. In addition to this, fuelwood demand increases due to influx of tourists. He concluded that in the near future, this may also affect the status of the undisturbed forests at the middle elevation and the information in this communication could be utilized for developing various conservation and sustainable strategies in the region to mitigate the impact of forest resource for fodder and fuelwood.

According to Ogunkunle *et al*., (2004) study, a survey of both urban and rural communities in five Local Government Areas(LGA) of Oyo State in Nigeria showed that 76% of households depend on fuelwood for cooking. The total annual wood consumption for fuelling by bread bakers, food sellers and in domestic cooking was 5984 metric tons for the region. The quantity of wood harvested for various purposes did not show a significant difference ($p<0.05$) among the five LGAs. Their study concludes that residents of Ogbomoso in Nigeria have not shown positive disposition to tree planting. It therefore suggests scientific tree conservation strategies aimed at improved burning of fuel wood and maximized use of timber products as complementary efforts to enforced tree planting for conservation of our forests.

Ikurekong (2009) worked on rural fuel wood exploitation in Mbolocal Govt. area, Nigerian coastal settlement. His study revealed that, 90% of the total energy requirement is from woody biomass. He also found that, deforested area increased by 43.80% in 2003 and concluded that, at this rate of destruction of the natural vegetation, there was no doubt that the loss of biodiversity is enormous.

Bahru *et al*., (2012) conducted ethnobotanical survey on fuel wood species used by the Afar and Oromo (Kereyu and Ittu) Nations in and around the semi-arid Awash National Park (ANP), Ethiopia. The study aimed to investigate and document various aspects of indigenous knowledge (IK) on fuel wood species and their associated threats. He noticed that overgrazing, followed by deforestation were the major threats in the study area, which scored 21.7% and 19.9% respectively.

There is a considerable pressure on the forests in India, as the per capita area of forest is only 0.109 ha against the average of 1.0ha for the rest of the world (Krishnamurthy, 1999). Collection of fuel wood, fodder and green manure from the forests in a non-sustainable manner has a drastic effect on the forest ecosystems in India (Anitha *et al*., 2003; Rai and Chakrabarti, 2001; Singh *et al*., 1992). Besides this, commercial harvest of timber over the past centuries has caused about 40 million ha of Reserved Forests to be degraded (Gadgil, 1991).

In India, non-sustainable extraction of forest resources such as fuel wood is one of the causes of deforestation, loss of wildlife habitats (Jha, 1999), and loss of species and diversity (Kakati, 1999; Ramesh, 2003; Verma *et al*., 1997).

The consumption of fuel wood is by now one of the most significant reasons for forest loss in many countries and the estimates indicate that fuel wood accounts for over 54% of the total global harvest per annum (Osei, 1993). The fuel wood demand in the country ranges from 96 to 157 million tons annually, including a rural demand of 80-128 million tonnes, thus raising the consumption level to 148- 242 kg per capita (Bhattacharya and Nanda, 1992).

Studies carried out in the Biligirirangaswamy Temple Sanctuary on vegetation have shown that highly disturbed sites have lower stem densities, species diversity and basal area than moderately disturbed sites(Murali and Hegde, 1998; Shanker *et al.*, 1998), and resource collection adversely affected the regeneration of the target plant species (Murali *et al.*, 1996; Sekar, 1999). These studies show that unregulated resource extraction has an adverse impact on the forest.

Management of forest resources has been practiced through history (Wells and Brandon, 1993). In order to meet the requirements of the Indian population in terms of fuel wood, fodder, medicinal plants and other products, it is necessary to increase the forest cover to 33% (Singhal *et al.*, 2003). It is also important to examine the links between the ecological socio-economic and cultural dimensions to manage the natural forest and to rehabilitate the degraded forests (Ramakrishnan, 2003).

Involving the local population in forest management and sharing of resource collection can help to maintain forests (Srivastava, 2000). For example, villagers in southern W. Bengal received 25% of the share of timber and minor forest products in return for helping the Forest Department to protect the forests

(Poffenberger and McGean, 1996). The village forest of Kallabbe, managed by the local people supports to reserve forests in the vicinity (Gadgil, 1993).

Similarly, the villagers living around the Buxa Tiger Reserve and the neighboring Jaldapara Wildlife Sanctuary, West Bengal are cooperating with the Forest Department to protect the forest against illicit tree fellers (Karlsoon, 1999). *Eriochrysis rangachari*, a rare endemic grass was considered to have become extinct; however it was maintained by the Todas of the Nilgiris because of its importance in their tribal culture (Puyravaud *et al*., 2003).

Goel and Bhel (2001) have studied the genetic selection and improvement of hardwood tree species for fuel wood production on sodic wastelands. Field trials were conducted using leguminous specie s like *Acacia auriculiformis, A.nilotica, Albizialebbeck, Acacia procera, Dalbergia sissoo, Leucaena leucocephala, Pongamia pinnata, Prosopis juliflora* and *Pithecellobium dulce.* Other tree species like *Azadirachta indica, Eucalyptus teriticornis* and *Terminalia arjuna*were also chosen for this study. *Prosopis juliflora* was the most promising species in terms of biomass productivity (68.7 tonne/ha) and fuel index (148.8) after 8 years of growth. *Acacia nilotica* ranked second.

Patrick and lowore (1999) have identified and discussed the management options of some indigenous firewood species of Malawi’s central region. This study proposes the local people's involvement in the management domestic firewood on a coppice rotation of five years upwards.

Indoor air pollution and health hazards

Burning of biomass emits several health damaging pollutants such as carbon monoxide, sulfur dioxide, nitrogen oxides, carbon dioxide, benzene, PAH and suspended particulate matter etc. These pollutants cause acute respiratory infections, chronic obstructive pulmonary disease, asthma, nasopharyngeal and laryngeal cancer, tuberculosis and diseases of the eye (Andrae and Merlet, 2001) in human beings. Low birth weight in children and cardiovascular diseases are also associated with indoor air pollution.

A great deal of attention has focused on particulate matter (PM) pollution due to their severe health effects, especially fine particles. Several epidemiological studies have indicated a strong association between elevated concentrations of inhalable particles (PM_{10} and $PM_{2.5}$) and increased mortality and morbidity (Perez and Reyes, 2002; Lin and Lee, 2004; Namdeo and Bell, 2005).

The most common indicator of fine particulate matter is $PM_{2.5}$, consisting of particles with an aerodynamic diameter less than or equal to a 2.5 µm. Ultrafine particles are typically defined as particles with an aerodynamic diameter <0.1 µm (EPA, 2004; Oberdorster *et al*., 2005). With regard to $PM_{2.5}$, various toxicological and physiological considerations suggest that fine particles may play the largest role in effecting human health. For example, they may be more toxic because they include sulfates, nitrates, acids, metals, and particles with various chemicals adsorbed onto their surfaces.

Furthermore, relative to larger particles, particles indicated by $PM_{2.5}$ can be breathed more deeply into the lungs, remain suspended for longer periods of time, penetrate more readily into indoor environments, and are transported over much longer distances (Wilson and Suh, 1997).

Mondal *et al*.,(2013) assessed the indoor pollutants generated form bio-fuels and LPG in villages of Burdwan, West Bengal. He has done sampling for sixteen days i.e one hour per day. The average SPM was found to be in the following order: cow dung>bamboo stick>carbon dust cake>gobar gas>LPG>mustard stick>paddy straw>jute stick respectively.

Taylor and Nakai (2012) assessed the level of toxic air pollutants in kitchens in rural Sierra Leone. The results showed that CO concentration for kitchens with wood and charcoal stoves were 44ppm and 77ppm respectively. In traditional stoves nearly 10% to 30% of fuel carbon ends up as incomplete combustion products (Zhang *et al*., 2000). The levels of CO and CO_2were significantlyhigher in biomass than fossil fuel (Khalequzzaman *et al*., 2010).

There are several problems associated with its collection and use as a household fuel (Nathan, 1996).There are also serious gender and health implications arising from rural energy consumption patterns (Batliwala, 1982). Studies conducted by Tremeer (1999), have shown to cause health impacts, climatic change and other environmental impacts due to consumption of different cooking fuels. According to Hulscher (1995), Aristanti (1996) and WHO, (1997) the whole cycle of activities from production to harvesting or collection, processing, transportation and combustion of biomass fuels involves a variety of health hazards in the rural areas of the developing countries including India.

Biomass fuel used for cooking results in widespread exposure to indoor air pollution (IAP) and affecting nearly 3 billion people throughout the world. Use of fuel wood poses both health and environmental hazards. There is a relationship between biomass fuel, infant mortality, and children’s respiratory symptoms (Rinne *et al*., 2007). Poor households have a higher risk of respiratory ailments correlating with the higher use of fuel wood or coal (Eberhard and van Horan, 1995; Mishra *et al.*,1999; IEA, 2002).

Indoor air pollution causes serious health hazards, especially for women and children (Cliff, 1992). Exposure to smoke form biomass fuel is associated mainly with nonmalignant disorders, including acute lower respiratory illness in children (Smith *et al*., 2000), chronic respiratory illness and symptoms in adults, especially in the women (Ellegard, 1996), pulmonary hypertension and consequent right sided heart diseases called cor-pulmonale (Sandoval *et al*., 1993), lung function changes (Norboo *et al*., 1991), possibly eye disorders, such as cataract and blindness (Mohan *et al*.,1989) and adverse pregnancy outcomes(Mavalankar *et al*., 1992).

Linkages between household energy technology, indoor air pollution, and greenhouse gas(GHG) emissions have become increasingly important in understanding the local and global environment and health effects of domestic energy use(Bailis *et al.*,2003).

According to Mohapatra (2009), air pollution due to burning of fuel wood for cooking purpose is alarming day by day in the tribal village of Bolangir Dist.of Orissa. About 85 household were selected for the study, which burn about 254 tonnes of fuel wood annually. A negative correlation exists between annual income and firewood consumption of household. Due to heavy use of firewood the health status of women and children are degrading day by day and they are more vulnerable to serious diseases like asthma, skin cancer and other respiratory diseases.

Mishra (2003), carried out research work on indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. His study reveals that, about two – thirds (66%) of children lived in households using biomass fuels and 16% suffered from ARI during the 2 weeks preceding the survey interview. After adjusting for child's age, birth order, nutritional status, mother's age at childbirth, education, religion, household living standard, and region of residence, children in households using wood, dung or straw for cooking were more than twice as likely to have suffered from ARI as children from households using LPG/natural gas or electricity.

Several studies have shown that particulate matter (PM) concentration in cooking place was about 8000 $\mu g/m^3$ against the national standard of 120 $\mu g/m^3$ in 24 hours average time. Similarly, the total suspended particle (TSP) was about

8,800 μg/m^3 against national standard of 230 μg/m^3, 21 ppm of carbon monoxide (CO) against national standard of 9 ppm in 8 hour average was found where biomass was used as fuel. Moreover, these studies have also shown that mortality and morbidity rates among children and women are extremely high due to acute respiratory infection (ARI) and chronic obstructive pulmonary disease (COPD). This clearly indicates that the major cause behind it is indoor air pollution.

A study by Parikh (1996) in Colombia expressed that women cooking in open fires had almost four times more chronic lung disease as compared to those cooking in other manner. The epidemiological studies have provided some evidence of an association between cataract or blindness and exposure to indoor smoke from household use of solid biofuels fuels such as animal dung, wood and crop residues (Mishra *et al.,* 1999; Zodpey and Ughade, 1999).

An increased incidence of chronic bronchitis, lung cancer, and acute respiratory infections has been attributed to cooking with biomass fuel (Omar, 1981 and Baucer,1984). Exposure to irritant gases produced during cooking on Chula (indigenous-cooking stove where biomass is used as fuel is considered a primary cause of bronchitis and chronic stove where biomass is used as fuel is considered a primary cause of bronchitis and chronic cor-pulmonale (Wig *et al.*, 1964 and Malik, 1977). Qureshi (1994), studied the domestic smoke pollutionand the prevalence of chronic bronchitis in rural Kashmir among Gujjar community. Cor-pulmonale (right-side heart failure) has been found to be prevalent and to develop earlier than average in non-smoking women who cook with biomass in India and Nepal (Pandey *et al*., 1988).

Asthma is the most prevalent chronic disease in childhood (Boner and Martinati, 1997) with increasing morbidity in most countries globally (Myers, 2000), making it a major public health problem. Epidemiological studies have shown an increasing trend in the prevalence of childhood asthma in different parts of the world (Peat *et al*., 1992, Shaw *et al*., 1990; Gerden *et al*.,1988; Perdizet *et al*.,1987). The risk of asthma is 1.59 times (women 1.83 and men 1.32 times) among rural households that use biomass fuel for cooking (Misra, 2003). The study also revealed the effect of cooking smoke on the prevalence of asthma in the elderly (>60 years) based on NFHS-II conducted during 1998-1999(GOI, 1994). Asthma and bronchitis take a major toll in India and have been recorded highest in Karnataka and lowest in the Punjab (RGI, 1994).

In India it was found that people expressed to this smoky fuel were at increased the risk of developing tuberculosis (Mishra *et al*.,1999) and in Spain a study has shown a strong association between exposure to wood smoke chronic obstructive pulmonary disease(Levi *et al.*, 2006).

Epidemiological studies have shown that an ultrafine and fine particle promotes inflammation in lung (Mukae *et al*., 2001; Ghio and Devlin, 2001; Nordenhall *et al*., 2000) through activation of lung epithelial cells and alveolar macrophages (Becker *et al*., 2003; Ishii *et al*., 2004; Suwa *et al*., 2002; Eeden, 2001). The particulate matter has detrimental impact on alveolar macrophage. It is known that biomass fuel smoke impairs alveolar macrophage function (Aam and Fonnum, 2007; Zhou and Kobzik, 2007) in human body. Particulate matter have shown the potential to impair alveolar macrophage immune response thereby increasing susceptibility to pulmonary infections (Pope III and Dockery, 2006; Sawyer *et al*., 2010).

Cooking with biomass fuels alters sputum cytology, oxidative stress and airway inflammation that might results in amplification of the tissue damaging cascade in women who is chronically exposed to biomass smoke. The study by Dutta *et al*., (2013) has reported the higher sputum levels of IL-6, IL-8 and TNF – alpha in biomass users. Also, compared with LPG users, sputum of biomass users contain more lymphocytes, neutrophils, eosinophils, alveolar macrophages, and showed presence of Charcot-Leyden crystals, Curschmann’s spiral and ciliocytophthoria.

Banerjee *et al*., (2012) investigated the possibility of inflammation and activation of neutrophil in response to indoor air pollutants in biomass users. Their work has shown that the neutrophil count in blood and sputum was significantly higher in biomass users than LPG users. Biomass users had 72%, 67% and 54% higher plasma levels of the pro-inflammatory cytokines TNF-alpha, IL-6 and IL-12, respectively. Also, the study reported that, blood and sputa of biomass fuel users contained more leukocyte count, eosinophils and lymphocytes.

One of the ways to overcome household air pollution problem is to energy transition or makes use of improved cook stove. Improved biomass cook stoves have been identified as an option to reduce negative impacts of cooking with traditional open fires (Masera *et al*., 2005; Mercado *et al*., 2011). Improvements to biomass stove have focused on combustion efficiency and the venting of emissions outdoors. Reduction in concentrations of PM <2.5μm in diameter ($PM_{2.5}$) and carbon monoxide have been reported due to the use of improved stoves in Mexico (Zuk*et al*., 2007). The concentrations of aerosol components and gases in the indoor air during the operation of improved cooking stoves (ICS) were found to be lower as compared to traditional cooking stoves (TCS) (Singh *et al*., 2014).

Improved biomass technologies contribute to more efficient and environmentally sound use of biomass energy. Improved cook stoves, for instance, are designed to reduce heat loss, decrease indoor air pollution, increase combustion efficiency and attain a higher heat transfer (Karekezi and Ranja,1997; Masera *et al*., 2000).There have been many attempts in the past to introduce improved fuel wood stoves with higher efficiencies for household cooking (Wijayatunga and Attalage, 2002).

Bates (2005) evaluated the impact of LPG use on household air pollution levels in Sudan. He reported that there were substantial reductions in particulate matter (51–80%) and CO (74–80%) levels in kitchen using LPG as fuel. LPG is a clean energy, burns efficiently and can significantly reduce cooking time and emissions.

Joshi and Srivastava (2013) had designed, fabricated and tested to evaluate the performance of three pot stove. Their investigations have shown that the improved three pot stove with wood burning rate of 0.17 kg/hr can handle fuel more efficiently and economically than traditional mud stove, showing a wood burning rate of 0.28 kg/hr. The thermal efficiency of improved three pot cook stove was found to be 28.4%, as comparedto the traditional mud stoves with 10.7%. The emission parameters of improved three pot cook stove showed 65.8% of SO_2, 70.2% of NO_2 and 76.1% of (Total suspended particulate matter) TSPM concentration reduction as compared to the traditional mud stove. The actual fuel wood saving was observed to be 30% when improved three pot cook stove was used as compared to the traditional mud stove.

A vast survey of the literature has thus revealed that there is an urgent need to find some solutions for energy crises, indoor air pollution and health hazards. This could be possible if proper assessment of energy security at national and local level was made. Lack of relevant exposure – response data is also considered to be a reason for increased exposure and health problems. Therefore, an assessment of level of indoor air pollution by pollutants emitted from biomass could provide clues or necessary data to standardize the exposure limits for such pollutants.Also, development of improvements in cook stove design and cooking area may often help to minimize health hazards.

Based on the above points, an integrated approach has been made in the present study to assess types of fuel used for cooking and health hazards associated with it in rural households of Chamarajanagara district with the following objectives.

Objectives of the study

1. Survey of the villages and identification of sites of the study area in Chamarajanagara district.
2. Collection of data pertinent to the total geographical area of the villages, population (number of houses and members in a family), energy sources of each village, total natural forest area and the total man-made forest area.
3. Identification and classification of fuel sources in each village.
4. Types of plant species used as fuel for utilization.
5. Estimation of fuel efficiency (individually and in combination) of different sources and their evaluation in different regions.
6. Purposes for which fuel is mainly used (domestic, rural industries and others).
7. Evaluation of types of health hazards due to different fuel sources utilization.
8. Possible suggestions for sustainable utilization and management of fuel wood resources and better health.

3. MATERIALS AND METHODS

Study area: Chamarajanagar district

Chamarajanagar district is located at 11^0 35' to 12^0 18' North latitude and 76^0 43' to 77^0 46' East longitude. The landscape of the area has hills and valleys (mountainous) and undulating area. This district has geographical area of 5676 Sq. Kms comprising a population of about 10, 20, 962 and accounts for 1.7 percent of the total population of the State. The district has the third lowest literacy rate of 61.4 percent in the State. This district comprises of four taluks namely Chamarajanagar, Gundlupet, Kollegal and Yelandur. The research work was carried out randomly in selected villages of each taluk of Chamarajanagar district (Fig.1).

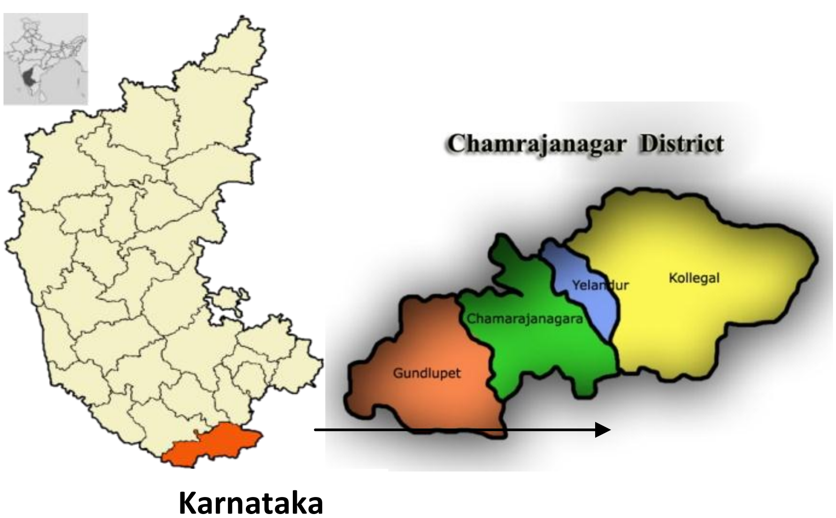


Fig.1 Study area.

Field exploration

The research work was carried out in randomly selected villages of each taluk of Chamarajanagar district. A standard questionnaire was used to collect the information regarding the population size, socio-economic conditions, energy use pattern, housing pattern, types of cook stoves and health hazards related to it. The energy usage included information on consumption of biomass fuels and commercial fuels for cooking and heating, sources of procurement of cooking fuel, time and effort involved in procurement. Biomass fuel procurements from sources, such as natural forests, village forests, avenues and wood depot were studied.

Housing characteristics included information on the type of house, number of rooms, type of kitchen, location of kitchen, and number of doors and window in the kitchen. Since indoor air pollution due to fuel combustion depends on the presence of chimney and adequate ventilation, the kitchen with or without chimney and ventilation for each household has been noted. The type of cooking device most commonly prevailing in the study area and its location in the house is also considered in the present study.

Fuel wood users were questioned for the possible risks and health hazards associated with biomass energy cycle. Health risks such as thorn pricks, cult and health hazards such as allergy, body ache, headache, burns, irritation of nostril and throats, cough etc., were recorded during the survey.

Estimation of calorific values of firewood species

Fuel value of wood is greatly dependent on its calorific content and is generally believed to be one of the parameters to compare one fuel with another. The wood samples of the tree species utilized by the rural folk were collected. The details of the firewood species used for determination of calorific value are shown in Table-1. The different wood samples were oven dried at 105°C, till the samples were dried to permanent weight. Oven dried samples were ground to fine powders. About one gram of powdered material was pressed to prepare pellets or capsule. Each of the samples of different firewood species were analyzed for determining calorific value using Bomb calorimeter.

Estimation of calorific values of briquettes

Preparation of briquettes: The wood materials were powdered and sun dried to remove moisture content in it. Powdered material of each sample was mixed thoroughly to get cylindrical shaped briquettes. A conveyor machine was used as moulder by the application of high pressure to form the briquettes. Each briquettes sample of different combinations was burnt in Bomb calorimeter for determining calorific value.

Determination of Percentage of Ash Content

2 g of firewood samples was put into an oven dried moisture free crucibles, and heated up to 575±25^0 C in muffle furnace for 3 hr. All analyses were done in

duplicate and the results were expressed on as is basis. The formula used to calculate percentage of ash content is follows,

$$\% \text{ of Ash content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Air sampling procedure for carbon monoxide and carbon dioxide

Indoor air sampling of CO, CO_2 and SPM was done for a period of 1 hour during cooking with different fuel types (Jackson, 2009). The concentration of CO and CO_2 was measured by portable CO (NDIR method, Model HTC-CO-1) and CO_2 meter (NDIR method, Model GCH-2018).

Air sampling procedure for suspended particulate matter

APM 821(Envirotech) handy sampler was used for sampling of SPM. The pre-weighed glass micro-fibre filter paper of 25mm diameter was placed in the filter cassette of the cyclone head. The flow rate of 1.5 L/min is set in the pump. The filter paper was reweighed after sampling for final weight. The concentration of SPM was calculated by using following equation,

Concentration of SPM (µg/m3) = (W2- W1)*103 / V
Volume of air sampled, V = (F1 + F2) / 2 * T
Where, W1= Initial weight of filter paper
W2= Final weight of filter paper
F1=Initial flow rate in m^3/min
F2=Final flow rate in m^3/min
T = Time period in minutes

Determination of morphology of suspended particulate matter

Morphology of suspended particulate matter was determined using Scanning Electron Microscopy (SEM-ZEISS). The SPM samples were collected over filter paper and examined under SEM.

Analysis of blood and sputum samples

Blood and sputum sample collection

Venus blood (up to 6ml) was collected in different tubes containing anticoagulating and clot activator for different tests (Complete blood count, Erythrocytes Sedimentation Rate -ESR and Elisa test). Early morning expectorated sputum samples were collected in sterile plastic container.

Assay used for complete blood count, total count and differential count

The blood samples collected in EDTA tube was subjected to automated hematological analyzer. The cell counts of different parameters were recorded.

Determination of ESR in blood samples

The blood sample collected in tri-sodium citrate tube was mixed thoroughly. The mixture was drown into Westergren tube (marked from 0-top to 200-bottom) up to zero mark and the tube set upright in a stand. The tube was not disturbed for an hour. The level of the top of the red cells in a column was read at the end of one hour.

Analysis of sputum samples

Pearl's Prussian Blue reaction and Pap stain technique were used for determination of hemosiderin and inflammatory cells.

Assay used to determination of IL-6 and TNF –alpha (ELISA)

The Enzyme Linked Immunosorbent Assay is a most commonly used technique for the detection of known analytes, based on antigen – antibody reaction. After antigen and antibody reaction, a colored complex is developed because of enzymatic reaction. The intensity of the colored complex is directly proportional to the concentration of analyte present in the samples. The absorbance of the colored complex is then measured to determine the concentration of sample tested. Samples were analysed for IL-6 and TNF –alpha using Diaclone kit.

Table 1:Fire wood species used for determination of calorific value

Sl. No	Scientific Name	Family	Vernacular Name	Habit	Distribution	Uses
1	*Prosopis Juliflora* DC	Leguminosae	Ballari jaali	A shrub or small tree (Evergreen tree)	South America, Central America, Caribbean, India	Fuel, gum, furniture and turnery items
2	*Acacia auriculiformis* A.Cumm	Leguminosae	Aurculis	Evergreen tree	Australia, India	Medicinal, handicrafts, shade, ornamental, fuel wood, charcoal
3	*Tamarindus indica* L	Leguminosae	Hunase	Evergreen tree/deciduous	Asia , Africa, Australia, America	Medicine, turnery works, jams, jellies, curries and confectionary.
4	*Albizia odoratissima* Benth	Leguminosae	Bilvar	Deciduous tree	Indomalaysia	Medicine, fuel
5	*Morinda tinctoria* Roxb	Rubiaceae	Maddi	Deciduous tree	India	Turnery works, red and yellow dye
6	*Casuarina equisetifolia* Forst	Casuarinaceae	Suragi	Evergreen deciduous tree	Indonasia, Malaysia, India, Sri Lanka, Australia	Medicinal, building material and fuel
7	*Syzigium cumini* Skeels	Myrtaceae	Nerale	Evergreen tree	Indomalaysia, Sri Lanka, Australia	Medicine, building material, edible juice, dyeing, furniture, fuel wood
8	*Ficus glomerata* Roxb	Moraceae	Athi	Deciduous tree	India, Malaysia, Pakistan, Australia	Local medicine, edible figs and shade
9	*Ficus religiosa* L	Moraceae	Arali	Evergreen tree	India, Vietnam, Pakistan	Medicine, fuel wood
10	*Artocarpus heterophyllus* Lam	Moraceae	Halasu	Evergreen tree	India	Medicine, furniture, turnery works and yellow dye
11	*Atalantia racemosa* Wight and Arn	Rutaceae	Kaadu nimbe	small tree or large shrub	India, Sri Lanka	Medicine, Pickles
12	*Sterculia villosa* Roxb	Sterculiaceae	Sowvve mara	Deciduous tree	India	Good fibre for ropes

13	*Actinodaphne malabarica Balak*	Lauraceae	Kaana more	Evergreen tree	South India	Medicine
14	*Soymida Febrifuga* A.Juss	Meliaceae	Soma hone	Deciduous tree	India, Sri Lanka	Medicine, fibre, medicine
15	*Cordia Obliqua* Willd	Boraginaceae	Selle	Semi evergreen tree	India, Myanmar, Sri Lanka, Australia, Egypt	Local medicine, vegetables, pickles
16	*Litsea laevigata* Gamble	Lauraceae	More mara	Evergreen tree	Southern Western Ghats	
17	*Eucalyptus globulus* Labill	Myrtaceae	Neelgiri	Evergreen tree	Australia	Medicine, oil, building material.
18	*Nothapodytes nimmoniana* Mabberley	Lcacinaceae	Moragaa di	Large shrub or small tree	South East Asia	Medicine
19	*Stereospermum colais* Mabberley	Bignoniaceae	Paadure	Deciduous to semi evergreen tree	South East India	Local medicine and building material
20	*Schefflera stellate* Harms	Araliaceae	Maruli	Deciduous shrub or tree	South India, Sri Lanka	Medicine
21	*Accacia catechu* Willd	Leguminosae	Kagguli	Deciduous tree	South India	Kachu a product used with betel and pan, tanning material
22	*Grewia damine* Gaern	Malvaceae	Nada dadasu	Shrub or small tree	Tropical Africa, India	Walking sticks
23	*Ficus amplissima* J.E.Smith	Moraceae	BiliEchh i	deciduous tree	South India, Sri Lanka, Maldives	Medicine and Handicrafts
24	*Mallotus Tetracoccus* Kurz	Euphorbiaceae	Jeneraku	Deciduous, evergreen tree	Inadia, Myanmar	Medicine

25	*Gmelina Arborea* Roxb	Verbenaceae	Kooli (Shivani)	Deciduous tree	Indomalaysia	Local medicine, boat building materials, musical instruments, dyeing
26	*Albizia Chinesis* Merr	Leguminosae	Kaadubaage	Deciduous tree	Indomalaysia	Building material, light furniture, Shade
27	*Chloroxylon swietenia DC*	Rutaceae	Urigilu	Deciduous tree	India, Sri Lanka	Toys and fuel
28	*Meliosma pinnata* Walpers	Subiaceae	Mustuka	Shola tree	Indomalaysia, China, Japan	Fuel wood
29	*Strychnos potatorum* L.f.	Logamiaceae	Sillana	Deciduous tree	India, Sir Lanka, Burma	Medicine, building materials
30	*Ixora pavetta* Andr	Rubiaceae	Goraga	Slender shrub or evergreen	India, Sri Lanka and Bangladesh.	Medicine, handicrafts, turnery works
31	*Miliusa tomentosa* Sinclair	Annonaceae	Asare	Semi evergreen tree	India, Sri Lanka, Myanmar	Cure weakness in children
32	*Erythroxylon monogynum* Roxb	Erythroxylaceae	Jeevdaale	Small tree	India	Turnery works
33	*Terminalia tomentosa* Wight and Arn	Combretaceae	Sunkumatti	Deciduous tree	India, Myanmar	Constructional works –railway sleepers
34	*Anogeissus latifolia* Wall	Combretaceae	Bejja (Dindiga)	Deciduous tree	India, Sri Lanka	Constructional works, agricultural implements, tanning, excellent fuel and charcoal
35	*Terminalia Chebula* Retz	Combretaceae	Alale	Deciduous tree	India, Myanmar, Sri Lanka	Medicine
36	*Glochidion zeylanicum* A.Jussieu	Euphorbiaceae	Kudugilu	Dioecious shola tree	Indomalaysia	Medicine
37	*Grewia tiliifolia* Vahl	Tiliaceae	Dadasu (Nagabala)	Tree	Africa, India, Myanmar, Sri Lanka	Medicine, building material, agricultural implements

50	*Acacia nilotica* Willd	Leguminosae	Gobbali	Nearly evergreen tree	India	Gum
51	*Pongamia pinnata* Pierre	Leguminosae	Honge mara	Evergreen tree	India	Medicine, fuel, oil, soap, shade
52	*Lantana camara* L	Verbenaceae	Kaanu lantana	thorny and deciduous shrub	Tropical region in Central and South America	Fuel wood, medicine, baskets
53	*Azadirachta indica* A.Juss	Meliaceae	Bevu	Evergreen tree	Myanmar, India, Nigeria	Medicine, furniture, soap and shade
54	*Ficus benghalensis* L	Moraceae	Aala	Evergreen tree	India, Sri Lanka, Pakistan	Local medicine
55	*Salix tetrasperma* Roxb	Salicaceae	Neeranj i	Tree	South East Asia	Medicine, good gun-powder charcoal, baskets, cricket bats
56	*Madhuca indica* Gmellin	Sapotaceae	Hippe	Deciduous tree	India, Sri Lanka	Medicine, building material, good manure
57	*Albizia amara* Boiv	Leguminosae	Selebaa ge Mara	Deciduous tree	India, Sri Lanka, Africa	Best fuel, soap nut powder
58	*Mangifera indica* L	Anacardiaceae	Maavu	Evergreen tree	Indomalaysia	Pickles
59	*Garuga pinnata* Roxb	Burseraceae	Arnelli	Deciduous tree	Indomalaysia	Gum, tanning
60	*Albizia lebbeck* Benth	Leguminosae	Kaduba age	Deciduous tree	Africa, Asia, America	Fuel wood, good charcoal, furniture, agricultural implements, shade

4. RESULTS AND DISCUSSION

The geographical area and location of the surveyed villages of Chamarajanagar district are tabulated in Table 2. The 20 villages selected for study are located between $11^{0}38'$ and $12^{0}14'$ Latitude and $76^{0}35'$ and $77^{0}35'$. The geographical area of the 20 villages is 34,669.95 ha. Among these villages, BR hills (9217.37 ha) is having highest geological area and lowest area is recorded in Katnavadi village (128 ha).The total human population is 61,216 persons living in 12,150 households. Of the 61, 216 persons, 31,062 (50.7%) were male population and 30197 (49.3%) were female population which is shown in Table 3.

In Chamarajanagar district, Kollegal taluk is having a vast natural forest area (193259 ha) followed by Yelandur (10589 ha), Gundlupet (44859 ha) and Chamarajanagar (26903 ha). The social forest area is under 63 ha, 80 ha, 45 ha and 75 ha in Kollegal, Chamarajanagar, Gundlupet and Yelandurtaluk respectively. The villages are surrounded with natural forest area are BR hills, MM hills, Sathegala, Ikkadahalli, Mangala (Bandipur), Kadabur and Bargi. The area under non-agricultural uses is 8395.59 ha, barren, un-cultivable land area is 769.25 ha, permanent pastures and other grazing land area is 838.94 ha and cultivable wasteland area is 959.72 ha ((Table 4). Un-cultivable, barren and cultivable wasteland areas could be used for energy plantation and social forestry programme. Often this helps to meet the biomass energy requirement of local people along with creating employment for the rural folk as an economic support.

Table 2. Geographical area and location of the selected villages of Chamarajanagara district.

Sl. No	Name of the village	Geographical location		Geographical area (In hectares)
		Latitude	Longitude	
1	A.Devarahalli	12^{0}04'	77^{0}05'	178.04
2	Malarpalya	12^{0}03'	77^{0}04'	294.35
3	Uppinamole	12^{0}01'	77^{0}01'	192.3
4	Katnavadi	12^{0}06'	77^{0}02'	127.97
5	Biligiriranganabetta	11^{0}59'	77^{0}08'	9217.37
6	Chandakavadi	11^{0}55'	77^{0}00'	219.53
7	Kethahalli	11^{0}55'	76^{0}47'	521.23
8	Bandigowdanahalli	11^{0}47'	76^{0}58'	873.1
9	Yaraganhalli	11^{0}44'	76^{0}50'	1098.18
10	Demahalli	12^{0}04'	76^{0}55'	642.23
11	Cowdalli	12^{0}03'	77^{0}26'	2176.81
12	Lokkanahalli	12^{0}01'	77^{0}14'	970.94
13	Mahadeshwarabetta	12^{0}02'	77^{0}35'	1755.67
14	Sathegala	12^{0}14'	77^{0}08'	8135.14
15	Ikkadahalli	12^{0}10'	77^{0}12'	2985.9
16	Sampigepura	11^{0}52'	76^{0}44'	272
17	Mangala	11^{0}38'	76^{0}40'	955.98
18	Kadabur	11^{0}42'	76^{0}49'	1087.84
19	Chikanapura	11^{0}53'	76^{0}41'	170.41
20	Baragi	11^{0}49'	76^{0}35'	2794.96

Table 3.Total population of the villages.

Sl. No	Name of the villages	Human population (In Numbers)		
		Male	Female	Total
1	A.Devarahalli	127	117	244
2	Malarpalya	467	435	902
3	Uppinamole	616	601	1217
4	Katnavadi	407	424	831
5	Biligiriranganabetta	1349	1349	2705
6	Chandakavadi	1847	1816	3663
7	Kethahalli	350	346	696
8	Bandigowdanahalli	620	580	1200
9	Yaraganhalli	684	704	1388
10	Demahalli	1017	998	2015
11	Cowdalli	4490	4330	8820
12	Lokkanahalli	2154	2123	4277
13	Mahadeshwarabetta	6488	6157	12645
14	Sathegala	6685	6389	13074
15	Ikkadahalli	1418	1372	2790
16	Sampigepura	174	175	349
17	Mangala	554	564	1118
18	Kadabur	122	131	253
19	Chikanapura	21	13	34
20	Baragi	1472	1573	2995
	Total	31062	30197	61216

Source: Department of statistics, Chamarajanagara district.

Table 4. Land-use pattern in the villages selected for investigation in Chamarajanagara district.

Sl. No	Name of the villages	Forest Area	Area under Non-Agricultural Uses (in Hectares)	Barren & Un-cultivable Land Area (in Hectares)	Permanent Pastures and Other Grazing Land Area (in Hectares)	Culturable Waste Land Area (in Hectares)	Total Unirrigated Land Area (in Hectares)	Area Irrigated by Source (in Hectares)	Net Area Sown (in Hectares)
1	A.Devarahalli	0	6.08	84.88	1	0	7.2	62.4	69.6
2	Malarpalya	0	65.7	0.38	3	45.29	99.23	80.4	179.63
3	Uppinamole	0	0	57.04	0	7.33	44.63	83.3	127.93
4	Katnavadi	0	8.06	4.8	0	0	2.4	111.2	113.6
5	Biligiriranganabetta	8916.83	38.53	0	0	0	208.44	53.2	261.64
6	Chandakavadi	0	0	42.3	0	0	60.81	85.9	146.71
7	Kethahalli	0	13.81	58.37	0	5.83	266.6	57.5	324.1
8	Bandigowdanahalli	0	298.41	0	0	10.27	366.3	128.5	494.8
9	Yaraganhalli	0	617.28	0	0	0	277.18	160.4	437.58
10	Demahalli	0	11	0	102	0	252	106	358
11	Cowdalli	0	16.3	90.23	15	290.35	1419.2	274	1693.2
12	Lokkanahalli	0	40	100	6.34	210.2	609.46	0	609.46
13	Mahadeshwarabetta	0	40.89	49.06	10.41	0	1524	74.8	1598.8
14	Sathegala	462	6370	0	0	30	1343	327	1670
15	Ikkadahalli	1055.2	151.7	0	0	323.5	1263	157.5	1420.5
16	Sampigepura	0	12.8	0	0	25.32	210.64	20.08	230.72
17	Mangala	205.07	22.03	3.02	289.59	11.63	130.8	31.5	162.3
18	Kadabur	525.8	4.84	241.15	12	0	281.65	20	301.65
19	Chikanapura	0	23.75	23.49	0	0	76.52	39.34	115.86
20	Baragi	764.82	654.41	14.53	399.6	0	776	167.6	943.6
	Average/total	11929.7	8395.59	769.25	838.94	959.72	9219.06	2040.62	11259.68

The survey data indicated that the majority of the respondents were farmers by primary occupation. Socio-economic characteristics of the surveyed villages are given in Table 5 and 6.

Table 5. Literacy level of respondents of household surveyed.

Sl.No	Name of the villages	Respondents (%)		Literacy (%)	
		Male	Female	Literate	Illiterate
1	A.Devarahalli	41	59	37	63
2	Malarpalya	57	43	52	48
3	Uppinamole	23	77	31	69
4	Katnavadi	44	56	39	61
5	Biligiriranganabetta	54	46	38	62
6	Chandakavadi	33	67	43.3	56.7
7	Kethahalli	69	31	31.7	68.3
8	Bandigowdanahalli	49	51	26	74
9	Yaraganhalli	64	36	46	54
10	Demahalli	66	34	35	65
11	Cowdalli	37	63	37	63
12	Lokkanahalli	39	61	35	65
13	Mahadeshwarabetta	43	57	40	60
14	Sathegala	53	47	42	58
15	Ikkadahalli	47	53	41	59
16	Sampigepura	38	62	39.4	60.6
17	Mangala	47	53	12	88
18	Kadabur	62	38	4.8	95.2
19	Chikanapura	78	22	44	56
20	Baragi	34	66	50.4	49.6
	Average/total	49	51	36	64

Among the respondents of the villages surveyed, the numbers of females are 51% and males 49 %; while illiterates are 64 % and literates are only 36 %. This indicates that the literacy level is low in these villages. Among these villages, the highest literacy rate is recorded in Malarpalya (52%), while lowest is in Kadabur villages (4.8%).

Table 6. Landholdings and annual income of the households.

Sl.No	Name of the villages	Landholdings (%)				Income (%)			
		Nil	Low	Medium	High	Nil	Low	Medium	High
1	A.Devarahalli	19	38	42	1	12.8	37	45.5	4.7
2	Malarpalya	14	36	48	2	16.7	56	24.6	2.7
3	Uppinamole	42	39.7	16.6	1.7	41.5	28	27.5	3
4	Katnavadi	34	25	38.5	2.5	35.3	39	20	5.7
5	Biligiriranganabetta	55.1	25	19.9	0	89	10.2	0.8	0
6	Chandakavadi	48	37.3	13.7	1	51	28	20	1
7	Kethahalli	24.75	25.75	47.5	2	10.9	33.7	51.5	3.9
8	Bandigowdanahalli	32.68	23.53	38.56	5.23	9.15	49.02	41.83	0
9	Yaraganhalli	34.4	10.7	54.4	0.5	4.7	32	60	3.3
10	Demahalli	41.7	20.6	36	1.7	9.7	38.9	49.1	2.3
11	Cowdalli	60.2	23.1	16.7	0	22.8	70.76	6.14	0.3
12	Lokkanahalli	36.49	32.63	30.53	0.35	20.7	53	25.6	0.7
13	Mahadeshwarabetta	70.1	21.4	8.5	0	19.8	72.5	7.7	0
14	Sathegala	68	18	14	0	20	67	13	0
15	Ikkadahalli	31	27	40.3	1.7	16.5	29	53.4	1.1
16	Sampigepura	8.4	28.2	62	1.4	11.3	57.7	22.5	8.5
17	Mangala	59.6	19.3	21.1	0	49	46	5	0
18	Kadabur	97.6	2.4	0	0	47.6	28.4	24	0
19	Chikanapura	0	44.4	55.6	0	11	44.5	44.5	0
20	Baragi	27	26.6	46	0.4	9.3	63.7	23.8	3.2
	Average	40.2	26.2	32.5	1.1	25.44	44.22	28.32	2.02

The households are categorized into four classes based on the landholdings such as landless or low (below 1 acre), middle (1–5 acre) and high (above 10 acre). Among these, the landless account for 40.2 %, the households with 1–5 acre account for 32.5 %, those below with 1 acre account for 26.2 % and households above 10 acre account for only 1.1 % of households. The households are classified into four types based on their economic status as; low (Rs.1,000-Rs.10,000), middle (Rs.10,000-Rs.50,000), high (>Rs.50,000) and without income. On an average, only 2.02 % of the population of households has annual income above Rs. 50,000, while 28.32 % below Rs. 50,000. Among these villages most of the households (44.22%) come under the category of low income level while 25.44% of the households have no fixed income as they are working as labourers in other farmlands on daily wages and below the poverty line. Because of this, the majority of them cannot afford to buy cleaner energy sources and therefore, depend much on easily available and economically feasible fuel wood resources.

Biomass is the primary source of energy in these rural households**.** Amongbiomass energy sources**,** firewood is the dominant source of energy in these villages for their daily requirement (Table 7).The villagers use mainly biomass fuel for cooking and heating purposes. The sources of energy available include fuel wood and agricultural residues, kerosene and liquid petroleum gas (LPG). They use different types of energy sources such as firewood and agricultural residues as traditional energy types while LPG and kerosene as modern energy types. The results of the investigation show that all the households of theses villages use firewood as their main energy source. Usage of LPG as energy source is relatively less in these villages. On an average 96.75% households are using firewood as primary and major fuel for cooking, followed by agricultural residues (58 %), kerosene (39 %) and LPG (36.6 %).

Table 7. Types of energy sources used as fuel by villagers

Sl. No	Name of the villages	Energy sources (% of households)			
		LPG	Kerosene	Firewood	Agricultural residues
1	A.Devarahalli	46	88	97	70
2	Malarpalya	42	40	98	87
3	Uppinamole	7	59	99	79
4	Katnavadi	49	36	85	80
5	Biligiriranganabetta	14	11	100	56
6	Chandakavadi	30	37	95	52
7	Kethahalli	16	5	100	82
8	Bandigowdanahalli	37	3	96	46
9	Yaraganhalli	37	40	99	69
10	Demahalli	23	25	94	50
11	Cowdalli	48	72	98	22
12	Lokkanahalli	62	65	89	67
13	Mahadeshwarabetta	58	64	100	25
14	Sathegala	44	5	98	18
15	Ikkadahalli	48	48	89	68
16	Sampigepura	44	11	100	89
17	Mangala	0	56	100	28
18	Kadabur	0	2	100	21
19	Chikanapura	44	89	100	80
20	Baragi	83	20	98	73
	Average	36.6	39	96.75	58

The use of kerosene is more as compared to LPG because of its easy availability. However, distribution of kerosene to each household is limited (2 to 3 Lt/household). Most of the rural folk prefer to use kerosene next to biomass fuel. It was observed that, none of the households are using coal, electricity and solar devices for cooking.

Gathering fuel wood involves a lot of hardship of walking for long distances and carrying head loads of fuel wood that can cause health disorders in individuals (mostly women and children) (Laxmi *et al*., 2003). It was noticed that, the average walking distance to collect fuel wood is about 2.3 km. They spend time around three hours to collect an average of 31 kg of fuel wood per day. The collected firewood is stored properly for longer time (Plate 1).

Table 8. Sources of biomass energy for rural households.

Sl. No	Name of the villages	Biomass energy sources				
		Farmland	Forest	Wood depot	Avenue trees	Village forest
1	A.Devarahalli	64.5	51.6	9.7	13	42
2	Malarpalya	86	32	8.2	32.7	19.4
3	Uppinamole	75.9	29.4	11.8	44	75.3
4	Katnavadi	73.7	22.8	9	49	66.5
5	Biligiriranganabetta	35.8	95.1	3	0	0
6	Chandakavadi	72	4.6	10.1	34.9	75.7
7	Kethahalli	91.1	1	14.9	12.9	45.5
8	Bandigowdanahalli	93.5	0.7	7.84	15	37.3
9	Yaraganhalli	93	3	2.3	3.7	65
10	Demahalli	80	1	21	17	48
11	Cowdalli	27	33	23	18	1
12	Lokkanahalli	68	1	0	33	4
13	Mahadeshwarabetta	33	66	1	0	0
14	Sathegala	64	15	32	17	67
15	Ikkadahalli	75	19	14	32	40
16	Sampigepura	94.4	0	0	9.9	35
17	Mangala	30	75	0	0	0
18	Kadabur	33.3	12.4	0	21.4	71.4
19	Chikanapura	100	0	0	0	0
20	Baragi	85.9	13	8.1	10.1	32.3
	Average	69	24	9	18	36

The survey data indicated that most of the fuel wood demand is satisfied through their own farmland sources as majority of the respondents were farmers by primary occupation (Table 8). To meet their energy requirements, households are dependent on farmland (69%) and village forest (36%) followed by natural forest (24%), avenue trees (18%) and wood depot (9%). Though, there is a restriction to collect firewood from the natural forest area, people used to collect dried fallen tree or branches or twigs for daily energy requirements. These efforts are almost done by women only, as they are the ones mainly associated with gathering, processing and transportation of fuel wood. Very few people are collecting the firewood from wood depots. Crop residues are generally collected from their own farmland as they grow major cereal crops. Jowar, Maize , Cotton, Seasam and Castor residues are used as fuel.

The results have shown that the consumption of firewood /household/day ranges from 2.9 kg to 5.1 kg (Table 9). The highest firewood consumption was recorded in the villages which are very close to natural forest. The results have shown that per capita consumption on firewood per day ranges from 0.72 kg to1.2 kg. It was recorded that, the consumption of fuel wood is more in the rainy season because of its usage in domestic purposes such as water heating. Also, in rainy season firewood absorb moisture content from the atmosphere. As the moisture content increased the combustion process decreased and it require more quantity of firewood.

Table 9. Average quantity of fuel wood utilized per household.

Sl. No	Name of the villages	Average Household size (A)	Per capita consumption (B in Kg)	Per household average fuel wood utilization (Kg)		
				Daily (AxB=C)	Monthly (Cx30=D)	Annually (Dx12=E)
1	A.Devarahalli	4.4	0.97	4.27	128	1536
2	Malarpalya	4.4	0.97	4.27	128	1536
3	Uppinamole	5	0.95	4.77	143	1716
4	Katnavadi	5	1	5	150	1800
5	Biligiriranganabetta	4.2	1.2	5.03	151	1812
6	Chandakavadi	4.4	0.98	4.3	129	1548
7	Kethahalli	4.1	0.97	3.97	119	1428
8	Bandigowdanahalli	4.3	1.11	4.77	143	1716
9	Yaraganhalli	4	1.07	4.27	128	1536
10	Demahalli	4.3	0.91	3.93	118	1416
11	Cowdalli	5	1.03	5.13	154	1848
12	Lokkanahalli	4.2	1.08	4.53	136	1632
13	Mahadeshwarabetta	5	1.01	5.07	152	1824
14	Sathegala	4.8	0.88	4.2	126	1512
15	Ikkadahalli	4.6	0.84	3.87	116	1392
16	Sampigepura	4	0.96	3.83	115	1380
17	Mangala	4	0.93	3.77	113	1356
18	Kadabur	4.2	1.06	4.47	134	1608
19	Chikanapura	4	0.72	2.87	86	1032
20	Baragi	4.3	1.07	4.6	138	1656
	Average	4.4	0.99	4.3	130	1564

The annual consumption of firewood in these villages is around 1.6 tonnes. The quantity of firewood utilization by the households mainly depends on type of fuel wood, household size and seasonal conditions. The investigation shows that there is a positive correlation between the household family size and the volume of firewood consumed per day (Fig. 2). A strong correlation (R^2 = 0.99) is found between the household size and quantity of firewood consumption.

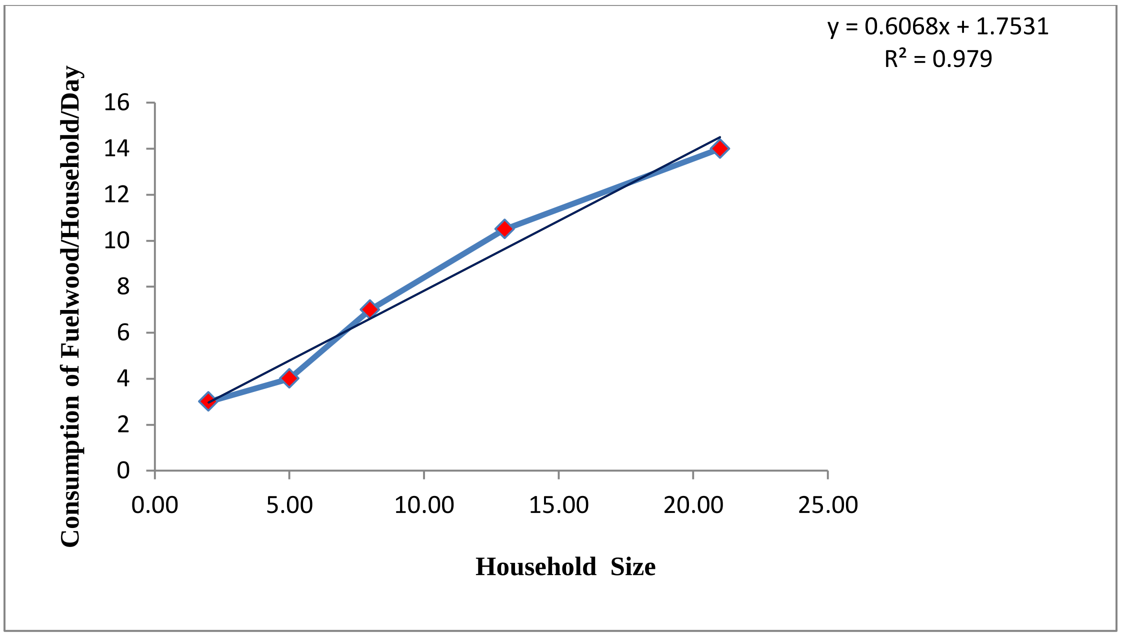


Fig. 2 Correlation coefficient between household size and fuelwood consumption.

The investigations observed that, the households use different types of stoves for cooking (Plate 2). Four types of stoves (Traditional, Clay, Metal and ASTRA) are used in these villages. The majority of the households use clay stove (34%) followed by Astra (26%), metal (24%) and three pot traditional (16%) stoves for biomass fuels. The results of the investigations suggest that, 74% of the households use inefficient cook stoves, which is a foremost concern and hindrance in addressing the problems associated with biomass utilization and of indoor air pollution in this region. It was observed that, roof, wall and utensils were covered with black soot particles due to combustion of biomass fuel under poorly designed cook stoves (Plate 3).

Clay stove has no chimney and consists of three bricks plastered with mud to form U shape with one side left open to feed fuel. People do not use single type of fuel, but they use multiple fuels or mixed fuels in these stoves. The traditional stove is made up of three stones, which requires more firewood than necessary. The traditional stoves using fuel wood have low thermal efficiencies of about 14 % (Ravindranath and Hall, 1995). The loss of heat is more in the traditional stoves as compared to other stoves. However, some studies have shown that the efficiency of a three-stone cooking stoves can be quite high if the fire is closely tended and managed (Dewees, 1999). While cooking in the traditional stoves, people use small and well dried wood pieces. Bembridge and Tarlton (1990) reported the preference of smaller pieces of firewood by gatherers as it tends to suit the traditional method of making fires. The results suggests that, households using traditional cook stoves put efforts to improve on the ventilation conditions of their cooking environment which influences the pollutants level and consequently increases the households susceptibility to health hazards associated with biomass smoke (Njeru, 2009).

ASTRA stove is found to be beneficial for the villagers as it is helpful in minimizing the deposition of particulate matter and consumption of firewood. Among these stoves Astra is considered as an improved cook stove because it is designed to capture maximum heat along with a chimney to remove suspended particulate matter generated during combustion. It is reported that the ASTRA improved stove had the highest PHU (Percent heat utilization-34%), considerably higher than the traditional stove fuelled with firewood (14.2%) (Ravindranath, 1997). The concentrations of aerosol components and gases in the indoor air during cooking with improved cooking stoves (ICS) were found to be lower as compared to traditional cooking stoves (TCS) (Singh, 2014).

However, household size, level of income and cost of cleaner energy sources are the governing factors for the households to make the choice of advanced cooking stoves. There are many other factors which determine the fuel choice, e.g. culture, social desirability and security of supply (Davis, 1998; Barnett, 2000). During our interaction most of the people have expressed their willingness to shift from using the traditional stove to improved stoves, if they are provided with improved stoves.

The cooking area and housing pattern were found to be different among the households. Most of the households cook at separate kitchen while others cook in living room and outside the house. It was observed that 59.7% of households used to cook exclusively in separate kitchen while 33.8% and 6.5% households used to cook in living room and outside the house respectively. Cooking in living area (room) may expose the people to longer periods of pollutants generated from the biomass smoke as compared to households cooking at separate kitchen or in open spaces. It was observed that only 55 % of households have cooking stoves with chimney and good ventilation for cooking. Thus, from the above data it can be predicted that the people in these villages are more prone to firewood smoke-related health problems. The ventilation and chimney are most important characteristics which help in reduction of indoor air pollutants.

However, the type of fuel sources, the cook stoves and the area cooking determines the concentration of the indoor air pollutants. This influences the households to different levels of health hazards associated with indoor air pollution.

Table 10: Commonly used firewood species.

Sl. No	Name of the Species	Sl. No	Name of the species
1	*Acacia nilotica* (Gobli)	10	*Acacia leucophloea* (Bili Jali)
2	*Ficus bengalensis* (Ala)	11	*Prospis juliflora* (Gobli)
3	*Albizia amara* (Chujli)	12	*Albizia lebbeck* (Dodda baage)
4	*Azadirachta indica* (Bevu)	13	*Morinda tinctoria* (Maddi)
5	*Cocos nucifera* (Tengu)	14	*Pongamia pinnata* (Honge)
6	*Ficus infectoria* (Basari)	15	*Acacia auriculiformis* (Jaali)
7	*Eucalyptus globulus* (Neelgiri)	16	*Lantana camara* (Roja)
8	*Tamarindus indica* (Hunase)	17	*Tectona grandis* (Thega)
9	*Casuarina equisetifolia* (Suragi)	18	*Cassia fistula* (Kakke)

The commonly used plant species as firewood are listed in Table 10 (Plate 4-10). Among these, the most preferredspecies are *Coccus nucifera*, *Prosopis juliflora*, *Lantana camara*, *Acaciaauriculiformis*, *Eucalyptus globulus* asthey can be easily grown in the farmlands. The dried species with higher wood density are preferred as fuel because of their high energy content per unit volume and their slow burning property (Singh and Khanduja, 1984; Goel and Behl, 1986). *Prosopis juliflora and Lantana camara* is widely found the wasteland study area. *Lantana camara* is having higher calorific value and less smoky properties (Sharma *et al*.,2014). The respondents explained that *Prosopis juliflora* serve as a good sources of firewood and easily available with no cost. The charcoal obtained from this wood of very high quality and can be produced as easily from green wood as from dried wood. It burns with a hot by giving high heating value as it has high density (Oduor and Githiomi, 2013).

The *Prosopis juliflora* emerged as the most popular among the local communities as a source of fodder and firewood (Choge *et al*., 2002). However, some times, due to short supply of preferred firewood, the rural households use substandard type of biomass such as leaves, twigs, rice and ragi straw and other crop residues. The use of rice husk and stalk of ragi and jowar as fuel was more frequent in poor households. Moreover, the consumption pattern and preferences for biomass fuels varied between the regions and socio-economic groups.

Ash content

The ash content of wood is very important if wood is uses as fuel. The ash content is the remaining inorganic part of wood matter that cannot be combusted. A high ash content of a plant part makes it less desirable as fuel, because a considerable part of the volume cannot be converted into energy (Joseph and Shadrach, 1997). It is one of the important parameters which directly affect the quality of fuel. A biomass having low ash content is considered better feedstock (Kataki and Konwrer, 2001; Channiwala and Parikh, 2002). Table 11 presents the ash content of ten firewood species. The analysis shows that among ten firewood species *Acacia catechu* has highest ash content (5.8%) followed by *Litsea glutinosa* (4.2%). *Grewia tiliifolia* has the lowest ash (1.3%) content, followed by *Cantunaregam spinosa* (1.7%), *Melotus tetracoccus* (1.8%) and *Ixora arboria* (1.95%). A high ash content is less desirable for fuel wood as it non-combustible and reduces the heat of combustion. However, our studies have shown that there is no significant correlation between the calorific value and ash content of the firewood species.

Table 11: Ash content of 10 firewood species.

Sl. No.	Name of the species	Calorific Value (cal/gm)	Ash content (%)
1	*Grewia tiliifolia*	5172	1.30
2	*Cantunaregam spinosa*	5908	1.70
3	*Ixora arboria*	3042	1.95
4	*Mallotus tetracoccus*	5071	1.80
5	*Acacia catechu*	4986	5.80
6	*Cassia fistula*	4897	3.05
7	*Meliosma pinnata*	6713	2.30
8	*Nathapodytes nimmoniana*	5348	2.10
9	*Gmelina arborea*	6134	2.33
10	*Litsea glutinosa*	5071	4.20

Several other studies have reported that there was no significant correlation between volatile solids content an higher heating value (Yang *et al.*, 2017), whereas heating value has mere significant correlation with ash and fixed carbon content. The ash content of biomass is known to vary between tree species and tree components. High ash content can decrease the heating value of biomass (Hakkila and Kalja, 1983; Voipio and Laakso, 1992). In addition, processing combustible material with high ash content requires more frequent residue removal, as well as increased boiler maintenance due to higher dust emissions (Hytönen and Nurmi, 2015).

The reasons as responded by the rural households for consuming biomass fuels without using LPG for domestic cooking are shown in Fig.3 and Fig.4.

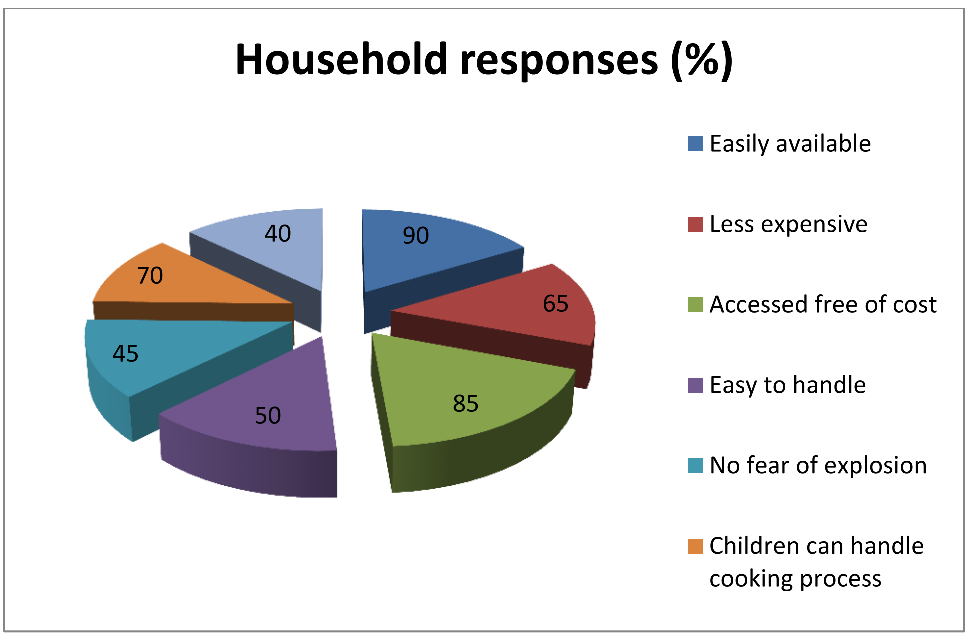


Fig. 3 Reasons for utilizing biomass fuels.

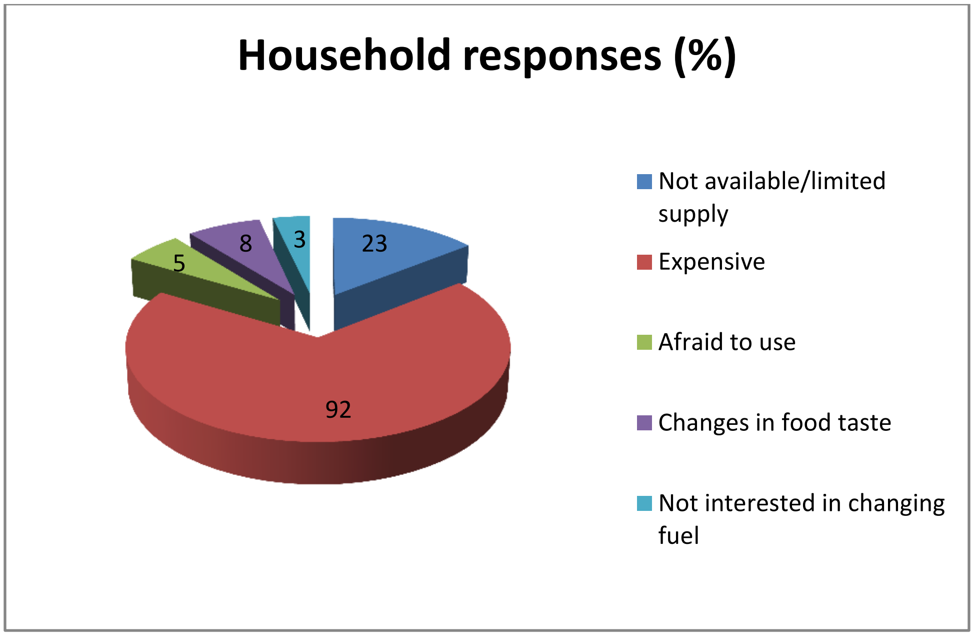


Fig. 4 Reasons for not utilizing cleaner fuel LPG.

Biomass utilizing households have expressed reasons for their dependency on biomass. Easy availability and accessed free of cost are the two important reasons stated by the households for using biomass. Majority of the households have expressed that the biomass is expensive than LPG. When it comes to purchasing of a cooking energy source, majority of the households prefer biomass rather than LPG. A study conducted by Vijay *et al.*, 2003 explains the similar reasons for consuming biomass fuel for domestic cooking. According to ESMAP (2001), it is usually more cost effective to purchase kerosene and LPG than fuel wood, if fuel efficiency is considered. Biomass utilization is found to be dominant in villages where it is available and where there is lack of LPG and kerosene source. In India, where almost 75% of the total population lives in rural areas, dependency on natural resources is common since varied biomass needs are met from surrounding vegetation

Kerosene and LPG are the least preferred and utilized cooking energy sources in the rural areas around Chamarajanagar district. Astra (1982) has reported that use of commercial energy such as kerosene and electricity accounts for a very small percentage of the energy used in villages, the remaining energy coming from firewood, which is typical of South Indian villages. According to TERI (2013), commercial fuels like LPG have achieved little penetration into the domestic sector, with only 2% of households using the fuel for cooking in Karnataka. Few households have found LPG and kerosene as affordable cooking energy sources. However, very less number of households are utilizing LPG or kerosene as the only cooking energy source. Households utilizing LPG and kerosene combination with biomass are more than those using them separately. .

Energy transition is generally occurring slower in rural areas as compared to urban areas (Gundimeda and Kohlin, 2008). Possible explanations for the lower rate of fuel switching in the rural areas include a lack of infrastructure for modern fuels (Leach, 1992), lower or non-monetary sporadic income, a traditional Life style and a lower opportunity cost of time in addition to the higher availability of collectible fuels. Additionally, the availability of biomass strongly influences the path of urban fuel switching (Branes *et al*., 2004).

Calorific value of firewood and briquettes samples

Table 12 shows the calorific values on as is basis of the sixty firewood species. Calorific value is one of the most important parameter to assess the combustibility of fuel wood. Calorific value is defined as the amount of heat that gives when it is burnt with excess of oxygen, at a given pressure and temperature. In this study finely powdered samples of firewood species were determined to know the calorific value (Plate 11-12) .The results have shown that, the heating (calorific) value of the samples ranged between 2387 cal/gm and 6843 cal/gm. The highest heating value was obtained in *Zizipus xylocarpa* (8643cal/gm) followed by *Casuarina equisetifolia* (7189 cal/gm) Grewia damine (6742 cal/gm), while *Soymida febrifuga* (2818 cal/gm) and *Syzizium cumini* (2387 cal/gm) shows lowest heating value.

The calorific value of the biomass depends on several physiological and climatic factors (Sagar and Kartha, 2007). The calorific value of the wood, besides moisture, is greatly influenced by the chemical composition of wood, mainly lignin and extractives (Jara). The quality of firewood is also related to some of its combustion characteristics. The important combustion characteristics which affect fuel wood properties are ignition temperature, peak temperature, maximum combustion rate, mean combustion rate and burnout temperature etc., (Sedai, 2014).

Table 12: Calorific value of firewood samples

SL. No	Scientific name	Local Name	Calories/gm
1	*Glochidion zeylanicum*	Kudugilu	3947
2	*Grewia tilifolia*	Dadasu (Nagabala)	5172
3	*Randia dumetorum*	Kaare	5908
4	*Dichrostachys cinerea*	Kasthuri jail	6134
5	*Cocos nucifera*	Thengu	4898
6	*Maytenus senegalensis*	Tandrasi	6131
7	*Shorea tumbuggaia*	Jaala	5781
8	*Cassia fistula*	Kakke	4897
9	*Terminalia tomentosa*	Sunku matti	3486
10	*Anogeissus latifolia*	Bejja (Dindiga)	3874
11	*Terminalia chebula*	Arale	6113
12	*Mallotus tetracoccus*	Jeneraku	5071
13	*Gmelina arborea*	Kooli (Shivani)	6134
14	*Albizia chinesis*	Kaadu baage	4131
15	*Chloroxylon swietenia*	Urigilu	6181
16	*Meliosma pinnata*	Mustuka	6713
17	*Strychnos potatorum*	Sillana	6071
18	*Ixora pavetta*	Goraga	3041
19	*Miliusa tomentosa*	Asare	5286
20	*Erythroxylon monogynum*	Jeevdaale	4894
21	*Azadirachta indica*	Bevu	5116
22	*Ficus bengalensis*	Aala	5784
23	*Tamarindus indica*	Hunuse	6071
24	*Albizzia odoratissima*	Bilvar	4816
25	*Morinda tinctoria*	Maddi	3907
26	*Casuarina equisetifolia*	Suragi	7189
27	*Syzizium cumini*	Nerale	2847
28	*Ficus glomerata*	Atti	4781
29	*Ficus religiosa*	Arali	3671

30	*Artocarpus heterophyllus*	Halasu	5111
31	*Atalntia racemosa*	Kaadu nimbe	5289
32	*Sterulia villosa*	Sowvve mara	4238
33	*Actinodaphne malabarica*	Kaana more	6294
34	*Soymida febrifuga*	Soma hone	2818
35	*Cordia oblique*	Selle	4567
36	*Litsea laevigata*	More mara	5071
37	*Eucalyptus globulus*	Neelgiri	3811
38	*Nothapodytes nimmoniana*	Moragaadi	5348
39	*Stereospermum colais*	Paadure	5196
40	*Schefflera stellate*	Maruli	3826
41	*Accacia catechu*	Kagguli	4986
42	*Grewia damine*	Nada dadasu	6742
43	*Ficus amplissima*	Bili Echhi	6103
44	*Albizzia stipulate*	Sele	5134
45	*Wrightia arborea*	Sunku beppale	6307
46	*Prosopis Juliflora*	Ballari jaali	4236
47	*Lannea coromandelica*	Godda mara	5193
48	*Aphanamixix polystachya*	Nayigantu	6811
49	*Lagerstroemia parviflora*	Chenngi	5614
50	*Zizipus xylocarpa*	Chotti mara	8643
51	*Salix tetrasperma*	Neeranji	5170
52	*Madhuca indica*	Hippe	3919
53	*Mangifera indica*	Maavu	4730
54	*Garuga pinnata*	Arnelli	6310
55	*Acacia auriculiformis*	Aurculis	4764
56	*Lantana camara*	Kaanu lantana	3814
57	*Tectona grandis*	Thega	4850
58	*Pongamia pinnata*	Hongemara	4350
59	*Albizia lebbeck*	Kadubaage	5038
60	*Ficus infectoria*	Basari mara	4375

Heat of the combustion is very important and fundamental property with regard to fuel quality and is usually the best means to compare one fuel with another. It was observed that, biomass fuel users have merely considered its availability rather than their calorific values. Trees with high calorific vales and which are suitable to be grown in rural areas of Chamarajanagar district are identified for energy plantation in the wasteland. Such trees provide better cooking energy source at the door step of the rural households. Also, pressure on the natural forests could be reduced. It was noticed that energy plantation programme has taken up in the study area (Plate-13).

The findings of calorific value of ten briquettes samples (Plate 14-15) are shown in Table 13. The results of the present investigation shown that, the heating (calorific) value of the samples ranged between 3562 cal/gm and 4411 cal/gm. The highest heating value was found in briquettes prepared from a combination of *Toona ciliate, Tectona grandis and Eucalyptus globulus* (4411cal/gm) followed by a combination of *Tectona grandis, Artocarpus heterophyllus and Ficus benghalensis Gmelina arborea* (4210) cal/gm), while a combination of *Ficus benghalensis, Eucalyptus globulus and Toona ciliata* shows lowest heating value (3562 cal/gm).

Table 13.Calorific value of briquettes samples.

Sl.No	Briquette combinations	Calorific value (Cal/gm)
1	*Toona ciliata + Tectona grandis+ Eucalyptus globulus*	4411
2	*Eucalyptus globulus +Azadhirachta indica +Artocarpus heterophyllus*	3643
3	*Grevillea robusta +Tectona grandis +Azadhirachta indica*	4028
4	*Ficus benghalensis + Acacia nilotica + Eucalyptus globulus*	4101
5	*Artocarpus heterophyllus +Toona ciliata + Acacia nilotica*	3697
6	*Toona ciliata +Tectona grandis +Grevillea robusta*	3830
7	*Ficus benghalensis + Eucalyptus globulus + Toona ciliata*	3562
8	*Azadhirachta indica +Artocarpus heterophyllus +Acacia nilotica*	4183
9	*Grevillea robusta+ Toona ciliata+ Ficus benghalensis*	3926
10	*Tectona grandis + Artocarpus heterophyllus+ Ficus benghalensis*	4210

Biomass briquettes with high calorific values are good cooking energy sources. Briquettes prepared with coal dust and saw dust of hart wood trees as the components produces less smoke. Conversely, the briquettes prepared using high percentage of agricultural residues, such as sesame and jowar stalk produce more smoke. Briquetting is an important technology to convert biomass wastes to energy. It burns more efficiently and emits less smoke compared to agricultural residues, cattle dung cakes and some firewood tree species

Table 14. Risks and health hazards associated with biomass energy cycle. (Responses form participants of clinical analysis) not of all the villages.

Activities	**Risks**	**Responses (%)**
Collection	Pricks from thorn	90
	Allergy	3.4
	Cuts	25
Transporting	Body ache	23
	Head ache	55
Processing	Pricks from thorn	20
	Cuts	8
Combustion	Eye irritation	65
	Throat irritation	9
	Allergy	2.1
	Burns	17
	Cough	50
	Head ache	36

General health risks associated with biomass energy cycle is shown Table 14. Pricks from thorn, allergy, cuts, head ache, body ache were the main reported health risks in collection, transportation and processing of biomass energy. Eye irritation, cough and head ache were the main reported health problems during combustion with biomass fuels under traditional cook stove. Allergy and throat irritation are rarely experienced by rural households. Several other studies have reported that spending hours for cooking in hazardous conditions in efficient stoves result rise to eye infections and other respiratory problems. These results were in agreement with Oyebanji *et al*., (2013) wherein biomass users have experienced catarrh, eye irritation, cough, sneezing, dry throat and nausea, shortness of breath, dizziness and skin irritation during cooking with biomass fuel.

Most of the women did not consider these respiratory ailments suffered by them as a serious problem probably because health problems from air pollution are known to be subtle (Mac, 2009) and serious outcomes take a fairly long latency period. The respiratory disease may have become quite frequent that the respondent might have developed means of coping with or they live by them Oguntoke *et al*., (2010).

Indoor air pollution

The study involves the assessment of indoor pollutants such as CO, CO_2 and SPM using handy samplers (Plate 16-17). The results have shown that people are using different types of energy fuels such as biomass, kerosene and LPG for cooking purpose. The fuel choice is depend on a number of factors such as affordability and accessibility of fuel, housing characteristics and income status.

Table 15 presents the concentration of indoor air pollutants (CO, CO_2 and SPM) generated during cooking for biomass fuels under different biomass cook stoves in the rural households (Plate 18). The highest CO concentration was recorded for traditional cook stove in Ikkadahalli and Demahalli followed by Malarpalya, BR hills and Kadabur while lowest in Chandakavadi, Bandigowdanahalli and Sathegala. The highest concentration of CO recorded for clay stove was in the following order; Mangala> Kadabur >Malarpalya > Bnadigowdanahalli > BR hills. In the metal stove it was in the order of Ikkadahalli> Malarpalya>Kadabur>Mangala. Similarly, for the Astra stove it was in the order of BR hills>Mangala>Kadabur>Uppinamole. The concentration of CO was ranged between 27 -50 ppm, 21-37ppm, 22-40ppm and 12-29 ppm for traditional, clay, metal and Astra cook stove respectively. The investigation revealed that use of traditional cook stove increases the level of CO as compared to other biomass cook stoves. The World Health Organization's one hour average CO standard is 35 mg/m^3 or nearly 30.5 ppm, and 60 mg/m^3 or nearly 52 ppm (CCOHS, 2014) for an average exposure of half an hour (WHO, 2010). The study finds that CO concentration exceeds the WHO standard while cooking with biomass fuels under traditional stone cook stove, clay and metal stove. WHO (2008) reported that breathing higher levels of carbon monoxide causes symptoms such as headaches, dizziness and weakness in healthy people. Once inhaled, CO binds to haemoglobin with an affinity 250-300 times than of oxygen (Raub, 2008), thereby forming carboxyhemoglobin (COHb). This results in a decrease in the amount of oxygen in blood, thus causing tissue hypoxia (Roughton and Darling, 1944; Piantadosi,1996).

The results also show that maximum CO_2 emission was observed for traditional cook stove followed by clay, metal and astra cook stove. The concentration of CO_2 for different biomass cook stove range between 345 to 2675ppm.The concentration of air pollutants such as CO and CO_2 were found to be significantly higher both in breathing zone (cooking area nearer to the challah) and also in the indoor ambient (non-cooking area) during cooking using biomass fuels in comparison to threshold limit value laid down by National Ambient Air Quality Standard (2000).

In a kitchen, the CO_2 concentration could be used as an indicator of the ventilation rate per person and also the adequacy of pollution removal. It was reported that air was not fit for breathing if the CO_2 concentration (due to human respiration) was greater than 1000 ppm. The National Institute for Occupational Safety and Health (NIOSH) considers that indoor air concentrations of CO_2 that exceed 1,000 ppm are an indicator suggesting inadequate ventilation.

This study revealed that there is variation in emission concentration of indoor air pollutants for different biomass cook stove. This could attributed to the cook stove design and cooking environment. This result clearly indicates that there is significant difference in pollutant concentration emitted from biomass fuel which burnt under traditional cook stove and astra cook stove.

The mean of SPM were ranges from 3251μg/m^3 to 8765 μg/m^3 for traditional cook stove, 1234 μg/m^3 to 4029 μg/m^3 for clay, 1387 μg/m^3 to 4123 μg/m^3 for metal and 1100 μg/m^3 to 2543 μg/m^3 for Astra stove. It was observed that generation of SPM is less in Astra stove which is properly designed with chimney. A chimney is a cement pipe having 10-15 cm diameter connected to stove. This chimney helps in removal of particles released during burning of biomass fuels. Chimney plays an active role in the performance of a stove by influencing the overall air to fuel ratio and subsequently the production of carbon monoxide (Prapas *et al*., 2014). Also, the study observed that the wall was getting covered with black soot particles during cooking with biomass fuels under traditional cook stove (especially the stove not connected chimney). This investigation revealed that there is possible reduction in indoor air pollutants generated during cooking with improved cook stove (Astra stove) in rural areas where biomass fuels are used as cooking fuels.

The highest concentration of SPM was recorded in Mangala for traditional cook stove whereas lowest was recorded in A. Devarahalli for Astra stove. The maximum SPM concentration recorded during cooking with biomass fuel is higher than the WHO Air Quality Guidelines (50 μg/m^3 for 24 hr). The studies carried out in rural households of India, pollutants emissions from the use of one kilogram of wood/hour in fifteen approximate footage of forty meter cubed kitchens emits, among others pollutants, carbon monoxide and particulate emission of 150 and 3.3 mg/m3 respectively compared to the allowable standard of 10 and 0.1 mg/m^3 respectively (UNEP, 1999). The concentration of suspended particulate matter in the range of 200-30,000 during the cooking period have been reported by Pandey *et al*., (1990) and Ellegard (1996). The rate of ventilation and size of kitchen is having influence on the pollutant concentration (Tian *et al*., 2008).

The concentration of indoor air pollutants (CO, CO_2 and SPM) generated during cooking with different fuels is presented in Table 16. The maximum concentration of Co, CO_2 and SPM was recorded for biomass fuels as compared to Kerosene and LPG fuels. Therefore, this investigation clearly indicates that LPG fuel is the least contributor for CO, CO_2 and SPM than biomass and kerosene fuel. Similar observations were recorded by Balakrishna *et al*., (2011). They have reported that the kerosene, coal or biomass have produced higher levels of gaseous pollutant than LPG gas or electricity in homes. Thus, there were substantial reductions in CO, CO_2 and suspended particulate matter levels in kitchen using LPG as fuel.

Morphology of suspended particulate matter

The suspended particulate matters were collected on micro-fiber filter paper during cooking with different fuels such as biomass, kerosene and LPG. These collected particles were analyzed under scanning electron microscope for morphological features (Plate 19). SEM was used to study the surface morphology of suspended particulate matter samples. During scanning, electrons are emitted from the surface which determines the brightness of the image. It was observed that the suspended particulate matter load was more in kitchen using biomass fuel for cooking as compared to kerosene and LPG. As shown in SEM images, the suspended particulate matters were irregular, spherical and angular in shape. Also, the size of the particles was varied among the different fuels. The morphology of carbonaceous particle varies depending on the fuels, burning conditions and atmospheric process.

Table 15: Concentration (ppm) of CO, CO_2 and SPM generated during cooking with biomass under different biomass cook stove.

Name of villages	Traditional			Clay			Metal			Astra		
	CO	CO_2	SPM	CO	CO_2	SPM	CO	CO_2	SPM	CO	CO_2	SPM
Yaraganahalli	32	1900	6072	21	1032	2500	25	903	3012	15	864	1958
Demahalli	46	2100	7050	26	972	2897	23	862	2098	17	718	1705
Bandigowdanahalli	28	1300	5437	32	1204	1983	28	968	2123	16	675	1200
Chandakavadi	27	1200	3251	28	668	1324	22	734	1987	12	456	1110
Kethahalli	32	1500	6423	30	900	1657	31	837	2807	14	576	1350
Chikkanapura	31	1298	4312	28	912	2842	33	633	4058	13	543	2405
Baragi	38	1509	4765	25	1200	1234	30	1098	3452	20	786	1200
Mangala	42	2004	8765	37	1300	3897	38	780	4500	29	754	2100
Sampigepura	36	1800	4563	27	1004	2674	29	765	2345	22	345	1876
Kadabur	42	1945	7654	34	956	3876	39	1029	4123	28	789	1720
Ikkadahalli	50	1940	6122	30	1350	3210	40	762	4010	25	813	2543
Sathegala	29	1600	3457	28	854	2345	22	567	2435	18	453	1245
MM hills	32	1900	6543	27	876	2689	30	987	3578	26	654	1546
Cowdahalli	30	1800	5647	30	567	2783	36	679	1387	27	476	1324
Lokkanahalli	36	2345	4509	28	798	2983	23	890	2787	17	567	1245
A.Devarahalli	30	1789	3587	25	890	2873	28	678	2546	15	487	1100
BR hills	43	2198	7213	31	1176	4029	37	965	4098	29	657	2087
Malarpalya	45	2675	5689	32	1142	3872	40	789	3987	26	700	2065
Katnavadi	31	1678	6753	25	867	2367	28	987	2804	18	546	1678
Uppinamole	29	1456	5498	29	756	2938	32	688	2543	28	502	1500

Table 16: Concentration (ppm) of CO, CO_2 and SPM generated during cooking with biomass, kerosene and LPG fuels.

Name of villages	Biomass			Kerosene			LPG		
	CO	CO_2	SPM	CO	CO_2	SPM	CO	CO_2	SPM
Yaraganahalli	23	1175	3386	13	657	1200	1	401	13
Demahalli	28	1163	3438	12	569	1401	3	532	23
Bandigowdanahalli	26	1037	2686	18		1456	2	324	15
Chandakavadi	22	765	1918	10	512	1098	1	457	12
Kethahalli	27	953	3059	17	678	1298	2	657	14
Chikkanapura	26	847	3404	14	732	1394	2	398	14
Baragi	28	1148	2663	33	675	1983	3	456	16
Mangala	37	1210	4816	34	876	2345	-	-	-
Sampigepura	29	979	2865	23	567	1765	2	554	23
Kadabur	36	1180	4343	31	765	2134	-	-	-
Ikkadahalli	36	1216	3971	16	712	1512	2	450	15
Sathegala	24	869	2371	25	542	1786	1	689	16
MM hills	29	1104	3589	32	675	1987	2	456	12
Cowdahalli	31	881	2785	29	765	1567	5	578	16
Lokkanahalli	26	1150	2881	17	546	1334	4	768	12
Chikkanapura	25	961	3433	15	659	1256	2	345	12
A.Devarahalli	35	1249	3357	18	512	1023	2	435	13
BR hills	36	1327	3903	32	745	2435	2	546	16
Malarpalya	26	1020	3401	18	690	2136	2	345	12
Katnavadi	30	851	3120	22	734	1987	1	467	13
Uppinamole	23	1175	3386	39	645	1954	1	623	15

Several other researchers suggest that particle size is an important factor that influences how particles deposit in the respiratory tract and effect on human health. Coarse particles are deposited in the nose and throat whereas, ultrafine particles are able to penetrate into the deep areas of the lung. The effect on the human organism is also influenced by the chemical composition of the particulate matter, concentration of pollutants, duration of exposure and vulnerability of an individual.

Clinical analysis

Haematology of the blood samples

Socio-demographic characteristics of voluntarily participated women involved in clinical examinations are given in Table 17. A total of 200 women aged between 23 to 48 years from study area were participated in this study. Out of 200 women participants, 100 were biomass users and used firewood, agricultural residues for cooking purposes where as others were LPG users. Majority of the participants were farmers by primary occupation. It was observed that biomass users were less educated than the LPG users. Also, most of biomass users are not having separate kitchen for cooking as they are generally cook at living room. It was noticed that half of the participants were not aware about health problems associated with utilization of biomass energy, as they are less educated.

The results of different haematological parameters of the blood samples of the participants are shown in Table 18 (Plate 20). Biomass using women had lowered haemoglobin and red blood cells levels as compared to LPG users. The level of haemoglobin and red blood cells (RBC) in LPG users was 12 g/dl and 4.5 Million/cmm while biomass users had 12.0 g/dl and 4.2 Million/cmm respectively. The platelet count (3.5Lakhs/cumm) in biomass users was more than the platelet count (3.1 Lakhs/cumm) of LPG users. However, there was significant difference was recorded in packed cell volume between biomass users and LPG users. Similar observations was made by Dewu *et al*., in 2012, where in study recorded that there was no significant difference in the packed cell volume and mean corpuscular volume (MCV) between biomass and LPG users.

Inhalation of pollutants generated during combustion for prolonged period may be the reason for platelet and leukocyte activation that can enable migration of leukocytes from blood to the tissues, initiating inflammation process (Ray, 2006). Biomass smoke pollutants mediated activation of the leukocytes and platelets increases the number of circulating leukocytes – platelets aggregates, which results in increase of the risk of cardiovascular diseases (Dutta *et al.*, 2013). Also, Pope *et al* (2004) observed that exposure to particulate matters were strongly associated with heart disease, heart failure and cardiac arrest. The findings of our investigation also supports some studies conducted by Pope III, *et al*., (1999); Salvi, *et al.*, (1999); Gold, *et al*., (2000); Schwartz, *et al*., (2001); Banerjee, *et al*.,

(2011) which recorded red blood cells and platelet levels in response to air pollution exposure.

Table 17. Socio-demographic characteristics of the participants involved in clinical analysis.

Parameter		**LPG users (n=100)**	**Biomass users (n=100)**
Age in year, mean (range)		36 (23-45)	37 (23-48)
Literates		55	35
Illiterates		45	65
Occupation	Household + agriculture	85	97
	Others	15	3
Kitchen	Separate	54	40
	Living room	46	60
	Out side	0	2
Ventilation	Good	30	17
	Average	64	68
	Poor	6	15
Cooking hours /day, range		1-1.30 hr	1-2.30hr
Years of cooking		2-15	3-25
Awareness about indoor air pollution and its health hazards	Yes	57	27
	No	43	81

Platelet activation is assumed to play a prominent role in the pathogenesis of all kinds of pulmonary arterial hypertension (Humbert *et al*., 2004). Interaction between activated platelets and inflammatory cells is important in pathogenesis of atherothrombosis and it may contribute to cardiovascular risk in patients with COPD. This suggests that this activation represents a novel mechanism linking COPD, inflammation and cardiovascular disease (Maclay *et al*., 2011). Elevated number of platelets was recorded in women with COPD than women with non-COPD (Dutta and Ray, 2013). The activated platelets release platelet basic protein and connective tissue activating peptide-III in high concentrations (Yee *et al*., 2009) along with growth factors, interleukins and chemokines that regulate inflammation (Snoep *et al*., 2010).

The investigation has shown that biomass users had more number of white blood cells (9,470 cell/cumm) than LPG users (8,081 cell/cumm). WBC's are more important in immune mechanisms in human body. According to Salvi *et al*., (1999) there is link between PM_{10} level, with the markers of adverse cardiovascular events such as increase in peripheral white cell counts. Relative to the use of LPG stoves, regular cooking with biomass aggravates systemic inflammation and oxidative stress that may increase the risk of cardiovascular disease (CVD) (Dutta *et al*., 2012).

Table 18. Haematological parameters of the blood samples of the participants.

Parameters	LPG users	Biomass users
Haemoglobin (g/dl)	12.5	12
Red blood cell count(Million/cmm)	4.5	4.2
Packed cell volume (HCT)(%)	33	32
Platelet count (Lakhs/cumm)	3.1	3.5
White blood cell count (cell/cumm)	8,081	9,470
Neutrophils (%)	55.1	60.3
Lymphocytes (%)	31.4	32.5
Eosinophils (%)	5.6	8.1
Monocytes (%)	2.03	2.04
Basophils (%)	0	0
Erythrocytes sedimentation rate (mm/hr)	16	23

Also, the results have shown that the biomass users had increased number neutrophils and eosinophils as compared to LPG users. Similar observations were recorded by Lahiri and Ray (2010) study wherein biomass users (women) had raised levels of WBC, neutrophil and eosinophil cell counts than control group (LPG users).

However, there was no significant differences were recorded in lympocytes, monocytes and basophils counts between LPG and Biomass users. Moreover, Erythrocytes Sedimentation Rates were found to be beyond the normal range (0 to 15 mm/hr) in both the groups. In biomass users it was 23 mm/hr, whereas in LPG users it was 16 mm/hr. High ESR indicates the presence of some inflammation, somewhere in the human body.

Air pollutants commonly found in biomass smoke have been shown to cause hematological alterations (Ray *et al*., 2003) and suppression of the lung's immunity in animal and human studies (Chang *et al*., 1990; Fujii *et al*., 2001; Mukae *et al*., 2001). Lymphocytes are the key players in maintaining the body's surveillance over infiltrating pathogens.

Indoor air pollution causes systemic inflammation and oxidative stress which mediates high blood pressure which is a major risk factor for atherosclerosis at all ages. Also, it has been found to increase the tendency for coagulation and platelet activation favouring atherosclerosis (Fausto *et al*., 2004). Platelets play a vital role in inflammatory process by releasing potent mediators at the inflammation site of the lung. It is mainly because of intravascular activation and also transmigration into inflamed tissues (Lindemann *et al*., 2001; Gowaz *et al*., 2005).

Sputum cytology

The very important defense cells in the lungs are the alveolar macrophages (AMs). They readily engulf fine particulate matter and microorganisms to ensure systemic function of the lungs in human body. It has been estimated that the total surface area of inhaled carbon within an AM is 13 times higher in women who cook with biomass fuels than a non-user and 7.5 times higher in children from biomass-using households (Kulkarni *et al*., 2005).

The stained sputum samples were observed under microscope (Plate 21).The investigations have revealed that biomass using women had elevated number of inflammatory cells in the sputum (Table 19). On an average the biomass using women had more number of neutrophils (60cell/hpf) than LPG using women (45 cells/hpf). Lymphocytes (32 cell/hpf), eosinophils (1.2 cell/hpf) and alveolar macrophages (16 cell/hpf) were also found more in biomass users. Alveolar macrophages were significantly increased in biomass using women, suggesting altered alveolar macrophage activity (Lahiri and Ray, 2010). This could be attributed to increased exposure to biomass smoke. Among the LPG users the inflammatory cells such as Neutrophils and lymphocytes were 45 and 26 cell/hpf respectively. Moreover, eosinophils and alveolar macrophages were found to be 0.7 and 9 cells/hpf. These results were in agreement with Lahiri and Ray where in biomass users had increased number of AMs and inflammatory cells such as neutrophils, eosinophils, and lymphocytes in sputum. These changes could be attributed to adverse lung response to particulate matter.

Response to the particular matter in lung is initiated by alveolar macrophages and air way epithelial cells. The inhaled carbonaceous particles generated from biomass smoke are phagocytosed by alveolar macropahges in air ways. The macrophages are more potent in production of pro-inflammatory mediators which contributes to local inflammatory reactions and the subsequent systemic inflammatory responses in the lung (Hogg and Eeden, 2009). Alveolar macrophages keep the air spaces clean in lung by removing all foreign materials thorough phagocytosis.

Table19: Inflammatory cells in sputum samples of the participants.

Parameters	LPG users	Biomass users
Neutrophils (cells/hpf)	45	60
Lymphocytes (cells/hpf)	26	32
Eosinophils (cells/hpf)	0.7	1.2
Alveolar macrophages (cells/hpf)	09	16
Siderophages (cells/hpf)	-	-

Airway neutrophilia plays a key role in the pathogenesis of pulmonary fibrosis and its magnitude correlates with lung function impairment (Beeh *et al.*, 2003; Fujimoto *et al.*, 2003). On the other hand, sputum eosinophilia (eosinophil >3% of total cells) is associated with eosinophilic bronchitis, chronic nonproductive (dry) cough, and wheeze (Gibson *et al.*, 2001; Ayik *et al.*, 2003; Fujimoto *et al.*, 2003). The presence of both neutrophilia and eosinophilia in sputum may indicate chronic obstructive lung disease in nonsmokers (Birring *et al.*, 2002).

However, there was no siderophages were found among the biomass and LPG users. The iron-containing macrophages are known as siderophages. The presence siderophages in sputum in high numbers is an indicator of either past intrathoracic bleeding or extravasations of red blood cells into the alveoli due to a sluggish blood flow (Grubb, 1994). Siderophage numbers were higher in winter when air pollution levels were high. Abundance of siderophages in sputum maybe due to microscopic hemorrhage in the inner airways is recognized as an indicator of adverse lung function to airborne pollution (Roy *et al.*, 2001). Moreover, Deposition of iron causes oxidative stress, inflammation and neutrophilic lung injury (Ghio *et al.*, 2000).

Pro-inflammatory cytokines (IL-6 and TNF-alpha)

The substances which also play a crucial role in the response to PM exposure are cytokines. Cytokines are a group of peptides and proteins used by the cells as signaling molecules to communicate with each other. Various cytokines participate in the cell response to PM. Tumor necrosis factor a (TNFa), IL-6, and IL-8 are three cytokines that have consistently been reported as important participants in the response to PM (Monn and Becker, 1999; Moreno *et al*., 2002). TNFa is a molecule that triggers many different inflammatory-related responses, like the activation and recruitment of inflammatory cells and activation of endothelial cells. IL-6 is also a proinflammatory molecule, and elevations in TNF-alpha levels induce the expression of IL-6.

Exposure to biomass smoke resulted in increased level of IL-6 and TNF alpha (Table 20). The investigation have showed that, the levels of proinflammatory cytokines such IL-6 and TNF alpha was more in biomass users than LPG users. In biomass user IL-6 and TNF alpha were found to be 38 and 24 pg/ml, where as in LPG users it was found to be 22 pg/ml and 16 pg/ml respectively. This study is in agreement with Banerjee *et al.,* (2011). They have reported that the apparently healthy women who actively engaged in cooking with biomass had 47.5pg/ml of IL-6 and 13.2 pg/ml of TNF alpha, whereas the women who cooked with LPG had 28.5 pg/ml of IL-6 and 13.2 pg/ml of TNF alpha. Also, they have reported that biomass user had 72% and 67% of higher plasma levels of

TNF alpha and IL-6 respectively. Significantly increased number of proinflammatory cytokines was found in blood of biomass user than LPG users, suggesting inflammation. The investigation suggested that chronic exposures to biomass smoke pollutants elicit inflammatory response through the upregualation of proinflammatory mediators.

Table 20: Pro-inflammatory mediators in serum samples.

Parameters	**LPG users**	**Biomass users**
IL-6 (pg/ml)	22	38
TNF –alpha (pg/ml)	16	24

Particulate matter has previously been found to induce interleukin- 6 (IL-6), interleukin-8 (IL-8) and tumor necrosis factor (TNF)-alpha production (Delfino *et al*., 2009; Vargas *et al*., 2003). Malondialdehyde (MDA), an indicator of oxidative stress, was also found to be elevated in rural populations exposed to HAP (Isik *et al*., 2005). HAP from burning of biomass fuel can be markedly reduced by clean cook stove interventions (Thomas *et al*., 2015), but residual levels of pollutants can remain high and can still pose significant health risks to household inhabitants (Oluwole *et al*., 2013).

Elevated levels of TNF alpha, IL-8 in COPD women may suggest that the inflammatory response to biomass smoke began at the airways, and then spread to the systemic circulation as evident from elevated IL-6 and CRP levels (Dutta *et al*., 2013). Also, other studies have reported that decrease in TNF-α concentration could indicate reduced cardiovascular stress and prothrombotic effects from decreased HAP (Olopade *et al*., 2017).

Several other studies have reported improved lung function (Heinzerling *et al*., 2016), decreased frequency of respiratory (e.g. cough, phlegm, wheeze, chest tightness), non-respiratory (e.g. eye discomfort, headache, backache) (Diaz *et al*., 2008) symptoms in intervention groups using improved cook stoves (Accinelli *et al*., 2014). Thus, shifting to cleaner fuels can reduce systemic inflammation.

However, among the respondents few women were affected with various diseases on exposure to wood smoke. They are suffering from bronchitis, asthma and other respiratory problems (Plate 22).

Plate 1

Storage of firewood and agricultural residue

Plate 2

Clay stove

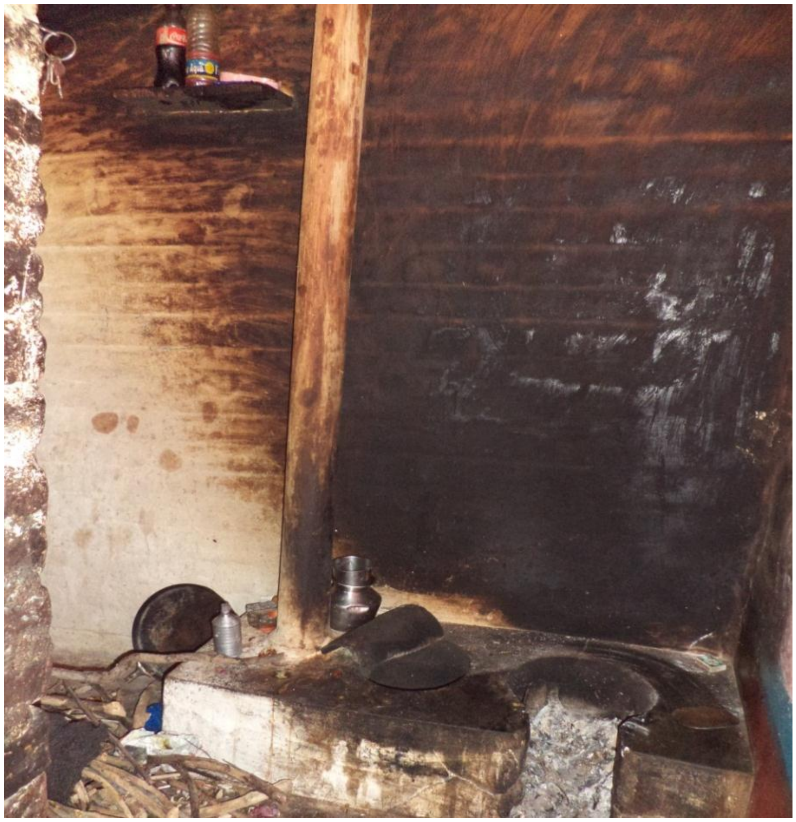
Traditional stone stove

Astra stove

Metal stove

Different types of biomass cook stove

Plate 3



Wall covered with black soot particles

Plates 4- 10 shows commonly used firewood species

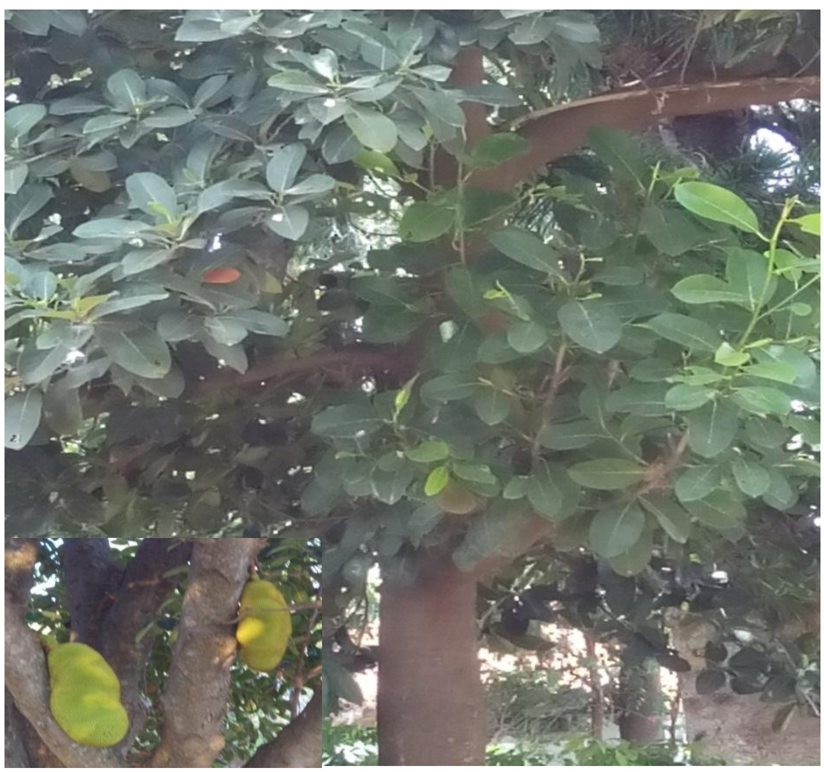
Plate 4

Prosopis juliflora

Acacia auriculiformis

Plate 5

Lantana camara



Artocarpus heterophyllus

Plate 6

Thespesia populnea

Tamarindus indica

Plate 7

Cocos nucifera

Casuarina equisetifolia

Plate 8

Eucalyptus globulus

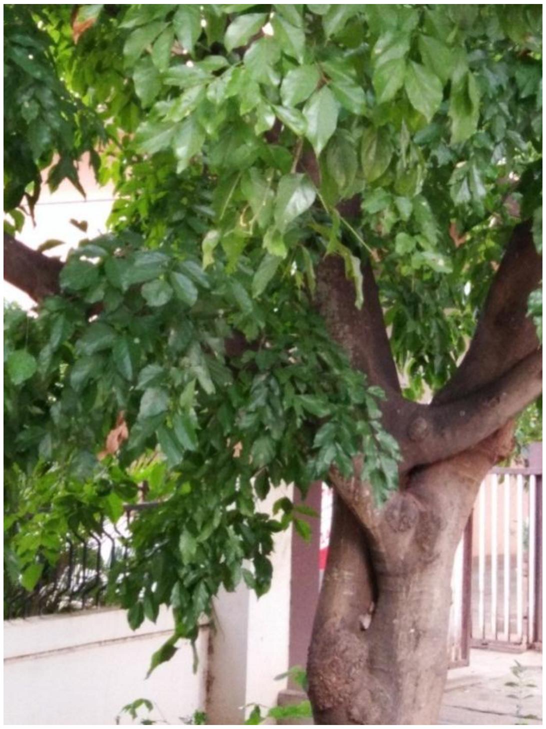
Delonix regia

Plate 9

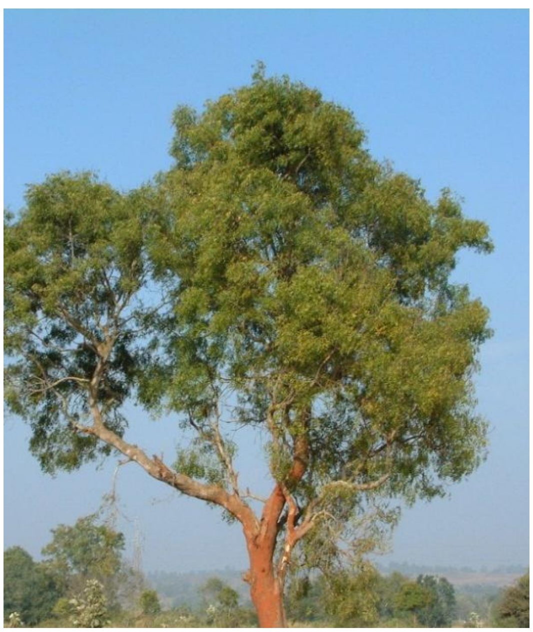
Syzygium cumini

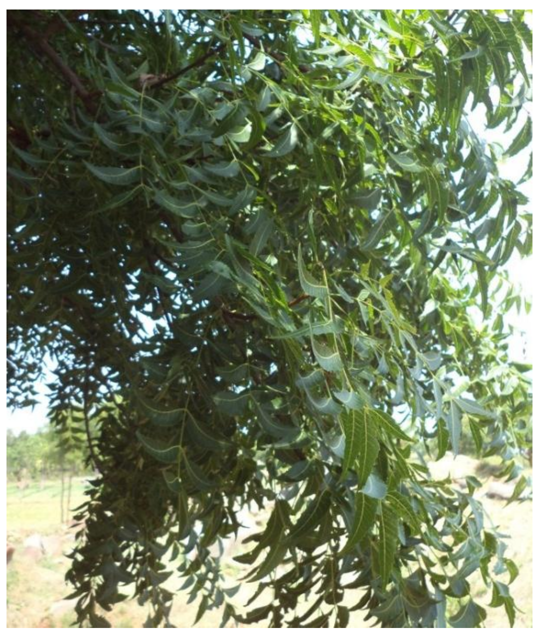
Morinda tinctoria

Plate 10



Pongamia pinnata





Azadirachta indica

Plate 11

Firewood samples collected for determination of calorific value

Plate 12

Powdered firewood samples

Plate 13

Women involved in energy plantation programme

Plate14

Prepared Briquette samples

Plate 15

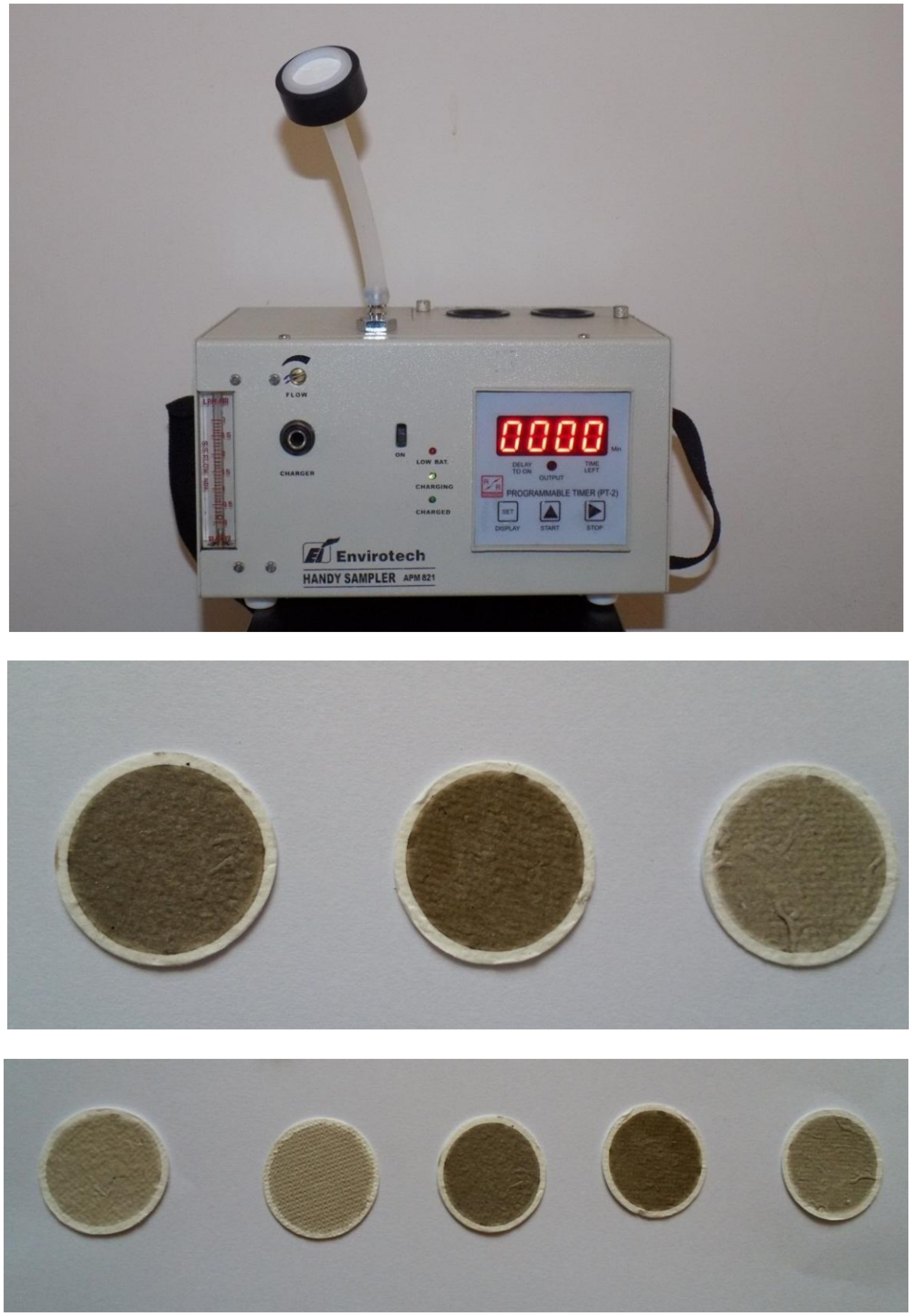
Briquette making machine

Bomb calorimeter

Plate 16

CO and CO_2 meter

Plate 17

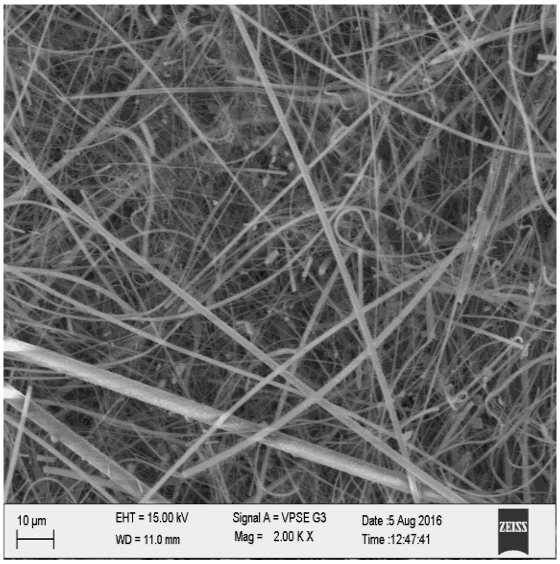


SPM handy sampler with filter papers

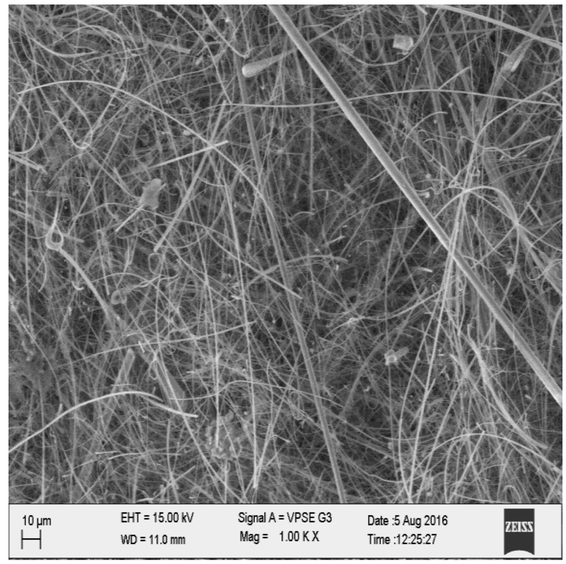
Plate 18

Measurement of indoor air pollutants

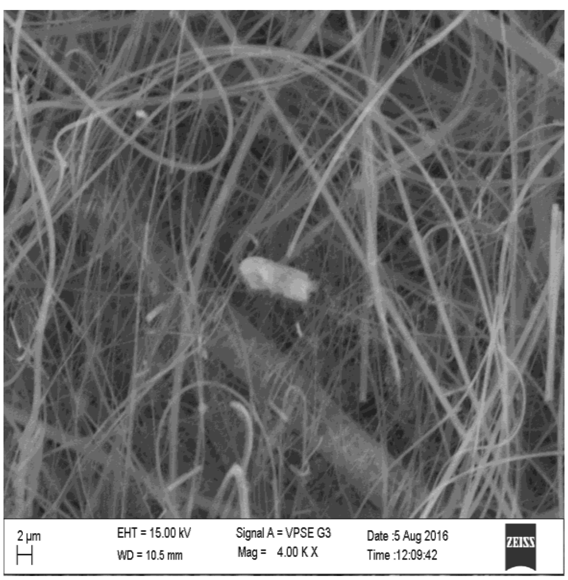
Plate 19



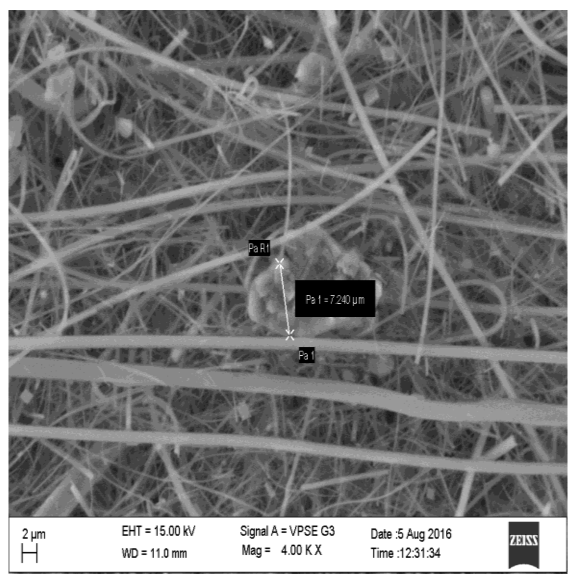
Control



LPG



Kerosene



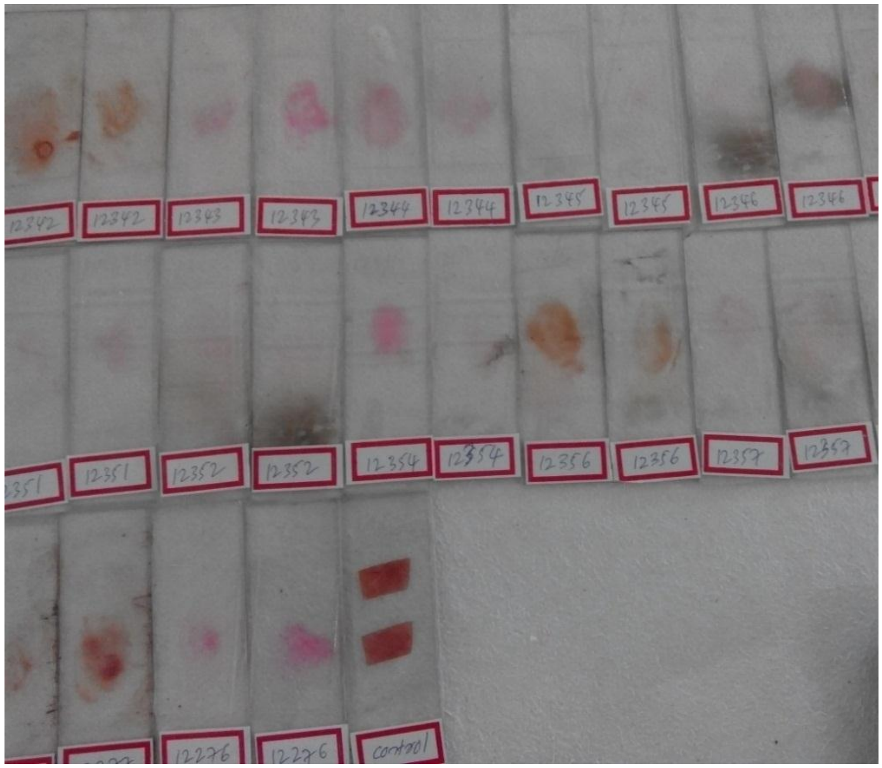
Biomass

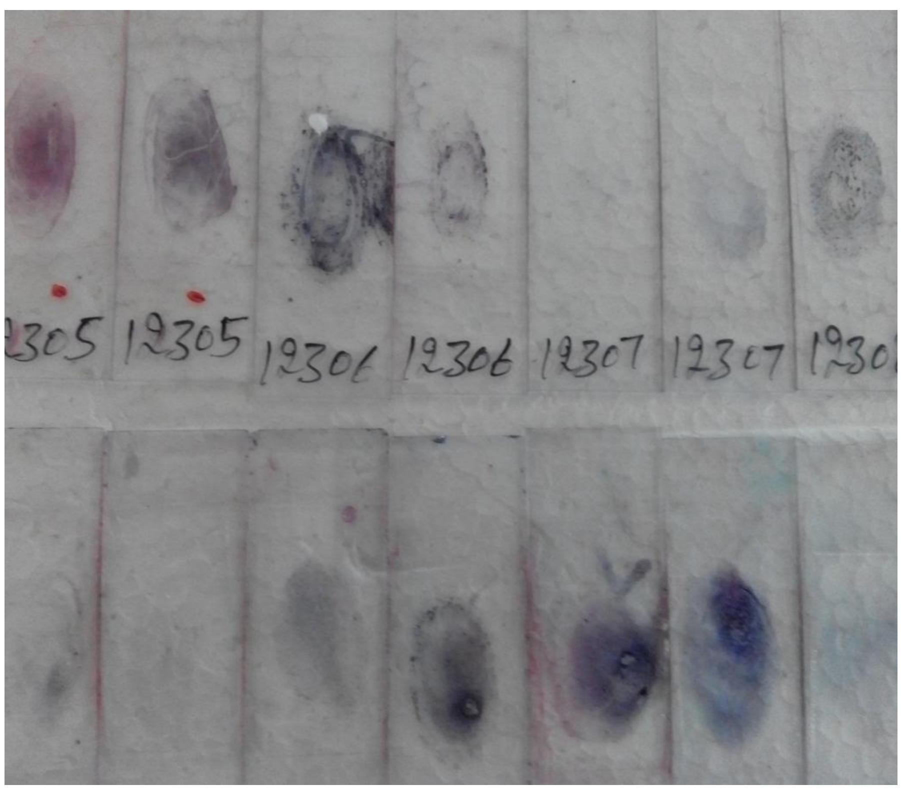
SEM images of spm of different energy sources

Plate 20

Blood samples collected in test tubes

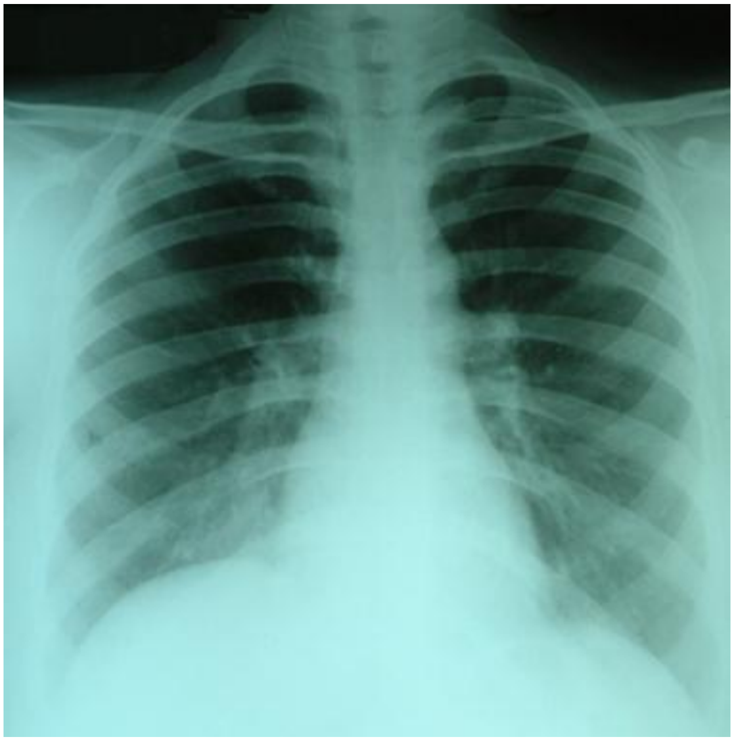
Plate 21





Stained sputum samples

Plate 22



Chest x-ray of normal women

Chest x-ray of women having lower respiratory tract infection

5. Conclusions

During the period 2013-2017, the project dealing with use biomass energy and its consequences have shown that, income factor has potential role in choice of cooking energy in rural households. The firewood fuel is the dominant source of energy for cooking and heating purposes in this study area. The traditional cook stove is used mainly for cooking and heating purposes. For many households, switching away from traditional biomass is not feasible in the short term. Training and awareness to use improved stoves such as ASTRA stoves can promote the better way of using biofuel sources. It was observed that rural households have been exposed to higher concentration of CO, CO_2 and SPM during cooking with biomass fuels, which increases the inflammation in lung airway leading to chronic obstructive pulmonary diseases in people.

The analyses show that the inertia of household cooking energy preferences is dueto poverty factors such as low income, low standing of living which in most cases meant no access to external or internal cooking facilities, large households, high cooking frequency of certain meals, etc. Also there are economic, technical, social and traditional constraints to complete switching to cleaner fuels. The determination of calorific values and analysis of smoke constituents of these fuel wood species can further help in identification of suitable species for better utilization of biomass energy. Recommendation of such species to be grown in wastelands of their vicinity helps in promoting self-sustenance and can reduce the pressure on natural forests for fuel wood species. The study also, strongly suggests the use of cleaner fuels, improved cook stove and maintenance of good ventilation in cooking area is helpful in reducing the indoor air pollutants and thus may benefit for better health of the households and environment.

Based on the results of the study the following suggestions have been made.

- Use of thermally efficient (high calorific value) firewood species can reduce the consumption of firewood.
- Plantation of multipurpose tree species that are fast growing with high calorific value should be encouraged; this practice helps to meet energy demand and economy of the rural people by providing employment opportunities.
- Promoting the utilization of waste products such as sawdust and agricultural residues directly or converting it into a briquette form as alternative fuel.
- Promoting energy plantation programme in wastelands of Chamarajanagar district for additional supply of firewood for domestic purposes. This practice will reduce pressure on woody species exploitation from natural forests.
- Training and awareness to use improved stoves such as ASTRA stoves can promote the better way of using biofuel sources.

- Use of cleaner fuel and improved cook stove reduces the indoor air pollution which results in reduction of health hazards associated with biomass energy utilization.
- Use of biogas offers a sustainable alternative fuel for cooking that is cost effective and easy to operate by the rural people.
- Local people's participation in sustainable production and utilization of fuel wood from locally available resources (mostly from existing natural forest and shrub/scrub and waste lands, and from existing depleted natural forest and shrub/scrub lands) should be encouraged. This will enhance the supply of fuel wood as trading item in rural areas.
- Government should provide some subsidy or incentives to buy cleaner fuels and improved cook stove. This often results in minimization of indoor air pollution and health hazards.
- Government should enforce a policy to promote use of cleaner fuels such as LPG and biogas.

Scope for future study

- Development of cost effective and thermally efficient biomass cook stove for rural folk.
- Determination of dose response ratio to set the standards for indoor air pollutants.
- Examine the role of other biomarkers in chronic obstructive pulmonary diseases.

6. Bibliography

Aam, B.B., and Fonnum, F., (2007): Carbon black particles increase reactive oxygen species formation in rat alveolar macrophages in vitro. *Arch. Toxicol*, **81**, 441–446.

Accinelli, R.A., Llanos, O., Lopez, L.M., Pino, M.I., Bravo, Y.A., Salinas, V., *et al*., (2014); Adherence to reduced-polluting biomass fuel stoves improves respiratory and sleep symptoms in children. *BMC Pediatr*. **14**, 12.

Alfaro Moreno, E., Martinez L., Garcia Cuellar C., *et al*., (2002); Biologic effects induced in vitro by PM10 from three different zones of Mexico City. *Environ, Health Perspect*, **110**, 715-720.

Andreae, M. O., and Merlet P. (2001): Emission of trace gases and aerosols from biomass burning. *Global Biogeochemical Cycles*, **15(4)**, 955-966.

Anon (1988); 'Forestry at Lule', Banko Janakari. *J. Forestry Infor. Nepal* **2(1)**, 60–67.

Anonymous (2002); *For.State Environ. Rep*., 190-192.

Andrea J. Venn, Haile Yemaneberhan, Zegeye Bekele, Sarah A. Lewis, Eldryd Parry and John Britton (2001); Increased Risk of Allergy Associated with the Use of Kerosene Fuel in the Home, *Am J Respir Crit Care Med*, **164**, 1660- 1664.

Arnold, M., Köhlin, G., Persson, R., and Sheperd, G., (2003); Fuel wood Revisited; What Has Changed in the Last Decade?.*Center for International Forestry Research Occasional Paper*, No. 39, Jakarta.

Arnold, M., Köhlin, G., and Persson, R., (2006); Wood fuels, livelihoods, and policy interventions; changing perspectives. *World Development*, **34(3)**, 596-611.

Arbex, M.A., Martins, L.C., De Oliveire, R.C., Pereira, L.A.M., Arbex, F.F., Cancado, J.E.D., et al., (2007); Air pollution from biomass burning and asthma hospital admission in a sugarcane plantation area in Brazil. *J. Epidemiol. Commun. Health*, **61**, 395–400.

Aristanti Christina (1996); Gender, Biomass Energy and Health,*Wood Energy News*, **12 (1)** 8-10.

ASTRA (Centre for the Application of Science and Technology to Rural Areas), (1982); Rural Energy Consumption Patterns - A Field Study. *Biomass*, **2 (4)**, 255-280.

Ayik S.O., Basoglu, O.K., Erdinc, M., Bor, S., Veral, A., and Bilgen, C. (2003); Eosinophilic bronchitis as a cause of chronic cough. *Respir Med*, **97**,695–701.

Bailis, R., Ezzati M., and Kammen, D.M. (2003); Greenhouse gas implications of household energy technology in Kenya. *Environ Sci Technol,*, **37 (10)**, 2051-59.

Baiyegunhi, L.J.S and Hassan M.B. (2014); Rural household fuel energy transition: evidence from Giwa LGA Kaduna State, Nigeria. *Energy for sustainable development*, **20**, 30-35.

Balakrishnan K. and Ramaswamy P., *et al*., (2011); Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Global Health Action.

Ballard Tremeer, G., (1999); Technical options for reducing emission and impacts in households. *Wood Energy News*, **14 (3)**, 23-25.

Banerjee,M., Siddique, S., Mukherjee, S., Roychoudhury, S., Das, P., Ray, M.R., and Lahiri, T.,(2011); Hematological, immunological and cardiovascular changes in individuals residing in a polluted city of India. A study in Delhi.*Int J Hyg Environ Health*, **215(3**),306-11.

Banerjee, A., Mondal N.K., Das, D., and Ray, M.R., (2012); Neutrophilic inflammatory response and oxidative stress in premenopausal women chronically exposed to indoor air pollution from biomass burning. *Inflammation*, **35**, 671–683.

Barnes, D.F., Krutilla, K., and Hyde, W., (2004); The Urban Household Energy Transition. Energy, poverty, and the environment in the developing worldWorld Bank Washington DC; 〈 https://www.esmap.org/sites/ esmap.org/files/ Rpt_UrbanEnergyTransition.pdf〉

Barnes, Douglas, and Michael Toman. (2006); "Energy, Equity and Economic Development," in Economic Development and Environmental Sustainability: New Policy Options, edited by Ramon Lopez and Michael Toman. Oxford: Oxford University Press.

Barnett, A. (2000); Energy and the fight against poverty. Department for International Development (Dfid), Livelihood Sector Report, UK.

Bartuska, A. M., (2006); Why biomass is important-The Role of USDA Forest Service in Managing and Using Biomass for Energy and Other Uses, 11th In the Distinguished Lecture Series, University of Florida.

Batliwala, S., (1982); Rural Energy Scarcity and Under nutrition. *Economic and Political Weekly*, **17 (9)**, 27.

Bates L (2005); Participatory methods for design, installation, monitoring and assessment of smoke alleviation technologies. Smoke, health and household energy. **1**. Rugby: ITDG.

Bauer M. A, Utell M. J, Marrow P.E, *et al*., (1984); PPM nitrogen dioxide inhalation potentiates exercise-induced bronchospasm in asthmatics. *Am Rev Respir Dis*, **129** (Suppl-A), 151.

Becker, S., Soukup J.M., Sioutas C, and Cassee, F.R., (2003); Response of human alveolar macrophages to ultrafine, fine, and coarse urban air pollution particles. *Exp Lung Res*,**29**: 29–44.

Beeh, K.M., Beier, J., Kornmann, O., and Buhl, R. (2003); Neutrophilic inflammation in induced sputum of patients with idiopathic pulmonary fibrosis. Sarcoidosis Vasc Diffuse Lung Dis 20: 138–143.

Behera Digambar, Tarun Chakrabarti and Krishan Lai Khanduja, (2001); Effect of Exposure to Domestic Cooking Fuels on Bronchial Asthma. *Indian J Chest Dis Allied Sci*, ***43(1)***, *1-5.*

Bembridge, T.J., and Tarlton, J.E.(1990); Wood fuel in Ciskei; a headload study, South African Forest Journal, **154**, 88-93.

Best Gustavo (1992); Energy, Environment and Sustainable Rural Development. *World Energy Council Journal*, WEC, London.

Bhatt, B. P and Tomar, J. M. S. *et al*., (2004); Characteristics of some firewood trees and shrubs of the North Eastern Himalayan region, India. *Renewable Energy*, **29**, 1401– 5.

Bhattacharya, B. and Nanda, S.K. (1992); Building fuel wood demand-supply scenario. *Journal of Rural Development*, **11**, 6p.

Bhattacharya, P.K., (2005); Biomass power generation and environment impact. ENREE, **78(9)**, 1078– 1092.

Blankenhorn, P. R., Bowersox, T. W., Kuklewski, K. M., Stimely, G. L., and Murphey, W. K, (1985); Comparison of selected fuel and chemical content values for seven Populus hybrid clones. *Wood and Fiber Science*, **17(2)**, 148-158.

Boner A.L and L.C. Martinati, (1997); Diagnosis of asthma in children and adolescents. *Eur Respir Rev*, 7, 3-7.

Bruce,N.,Perez Padilla,R..,and Albalak,R.(2000); Indoor air pollution in Developing countries: A Major Environmental and Public Health Challenge. *Bulletin of the world Health organization*,**78(9)**,1078-92.

Canadian Centre for Occupational Health and Safety (CCOHS)(2014); Converting Occupational Exposure Limits from mg/m3 to ppm, http://www.ccohs.ca/oshanswers/chemicals / convert.html.

Cecelski, E., (1995); From Rio to Beijing: engendering the energy debate. *Energy Policy,* **23 (6)**, 561-575.

Chang, J.C., Distler S.G and Kaplan A.M (1990); Tobacco smoke suppresses T-cells but not antigen presenting cells in the lung -associated lymph nodes. *Toxicol Appl Pharmacol*, **102**, 514-523.

Channiwala S.A., and Parikh P.P (2002); A unified correlation for estimating HHV of solid, liquid and gaseous fuels. *Fuel*, **81**, 1051-63.

Choge S.K, Ngunjiri F.D, Kuria M.N, Busaka E.A, and Muthondeki J.K (2002); The Status and Impact of Prosopis spp. in Kenya. KEFRI, Nairobi, Kenya. P. 59.

Cliff, J., (1992); Indoor air pollution and acute respiratory infections in children. *Lancet,* **339**, 396-398.

Davis, M (1998); Rural household energy consumption: the effects of access to electricity-evidence from South Africa. *Energy Policy,* **26(3)**, 207–217.

Daya Ram Nhuchhen, P and Abdul Salam (2012); Estimation of higher heating value of biomass from proximate analysis; A new approach. *Fuel*, **99**, 55-63.

Delfino, R.J., Staimer, N., Tjoa, T., Gillen, D.L., Polidori, A., Arhami, M., *et al*., (2009); Air pollution exposures and circulating biomarkers of effect in a susceptible population: clues to potential causal component mixtures and mechanisms. *Environ. Health Perspect*. **117 (8)**, 1232–1238.

Demirbas A., (2003); Energy and environmental issues relating to greenhouse gas emissions in Turkey. *Energ.Convers. Manage*, **44**, 203-213.

Desai V. (1991); Forest Management in India: Issues and Problems. Himalaya Publishing House. Bombay, Delhi, Nagpur.

Devendra Sharma, Komal Chandrakar, Daneshver Kumar Verma, and Yadav K.C.(2014); A Study on Consumption Trends of Fuel Wood & their Impact on Forest in Kanker Forest Division of Chhattisgarh State (India), International Journal of Scientific and Research Publications, **4(1)**.

Dewees, P.A., (1989); The woodfuel crisis reconsidered: observations on the dynamics of abundance and scarcity. *World Development*, **17(8)**, 1159-1172.

Diaz, E., Bruce, N., Pope, D., Diaz, A., Smith, K.R., Smith-Sivertsen, T., (2008); Self-rated health among Mayan women participating in a randomised intervention trial reducing indoor air pollution in Guatemala. *BMC Int. Health Hum. Rights*, **8**, 7.

Dutta, A., Ray, M. R., and Banerjee, A., (2012); Systemic inflammatory changes and increased oxidative stress in rural Indian women cooking with biomass fuels. *Toxicol Appl Pharmacol*, **261(3)**, 255–62. doi: 10. 1016/j.taap.2012.04.004 PMID: 22521606.

Dutta, A., Roychowdhury, S., Chowdhury, S., *et al*., (2013); Changes in sputum cytology, airway inflammation and oxidative stress due to chronic inhalation of biomass smoke during cooking in premenopausal rural Indian women. *Int.J.Hyg Environ Health*, **216(3)**, 301-8.

Dutta A, and Ray M.R (2013); Changes in sputum cytology, airway inflammation and oxidative stress due to chronic inhalation of biomass smoke during cooking in premenopausal rural Indian women. *Int J Hyg Environ Health*, **216**, 301-308.

Eberhard, A. and Van Horan, C. (1995); Poverty and power. Pluto Press. International Energy Agency. World Energy Outlook. IEA, Paris.

Eckholm, E.P., (1975a); The other energy crisis: Firewood. Worldwatch Paper No. 1, World watch Institute, Washington, D.C.

Eckholm, E.P., (1975b); The little-known crisis: Firewood scarcity in the human habitat. CERES, FAO, Rome.

Eckholm, E.P., (1976); Other energy crisis: Firewood. *The Ecologist,* **6 (3)**, 80-86.

Eeden, S.F.V., Tan, W.C., Suwa,T., *et al*., (2001); Cytokines involved in the systemic inflammatory response induced by exposure to particulate matter air pollutants (PM10). *Am J RespirCrit Care Med*, **164**, 826–830.

Eleri E.O, Ogwu O, Onuvae P (2012); Expanding access to pro-poor energy services in Nigeria Abuja, Nigeria. International center for energy, environment and development.

Ellegard A (1996); Cooking fuel smoke and respiratory symptoms among women of low income areas of Maputo. *Env Health Perspect*,**104**, 980-85.

Energy Sector Management Assistance Programme (2001); Annual Report 2000-2001, World Bank.

EPA (2004); Air Quality Criteria for Particulate Matter. **3**. 600/P-95-001cF. Washington DC: U.S. Environmental Protection Agency, Office of Research and Development.

Evert Thomas , David Douterlungne, Ina Vandebroek, Frieke Heens, Paul Goetghebeur and

Patrick Van Damme (2011); Human impact on wild firewood species in the Rural Andes community of Apillapampa, Bolivia, *Environmental Monitoring and Assessment*, **178**, Issue 1–4, 333–347.

Ezzati, M., Mbinda,B.M, and Kammen,D.M., (2000); Comparison of emissions and residential exposure from traditional and improved biofuel stoves in rural Kenya. *Environ Sci Technol,* **34**, 578-583.

FAO,(2005); Trends in forest products 1961-2003. Rome: Food and Agriculture Organization of the United Nations.

Fausto, N., Kumar, V., and Abbas, A.K., (2004); Robbins and Cotran's Pathologic Basis of Disease. Elsevier Saunders, Philadelphia, PA.

Fujii, T., Hayashi, S., Hogg, J.C., Vincent, R., and Van Eeden S.F., (2001); Particulate matter induces cytokine expression in human bronchial epithelial cells. *Am J Respire Cell Mol Biol*, **25**, 265-271.

Fujimoto, K., Yamaguchi, S., Urushibata, K., Koizumi, T., and Kubo, K. (2003); Sputum eosinophilia and bronchial responsiveness in patients with chronic non-productive cough responsive to anti-asthma therapy. *Respirology*, **8**; 168–174.

Gadgil, M., (1991); Conserving India's biodiversity; the societal context. *Evolutionary Trends in Plants*,**5(1)**, 3-8.

Gadgil, M., (1993); Biodiversity and India's degraded lands. *Ambio*,**22**, 167- 72.

Gerden, P.J., D.I. MuUaly and R. Evans, (1988); National survey of prevalence of asthma among children in the United States, 1976-1989. *Pediatrics,* 81, 1-7.

Ghio A.J., Kim, C., and Devlin, R.B. (2000); Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers. *Am J Respir Crit Care Med*, **162**, 981–988.

Ghio, A.J, and Devlin, R.B., (2001); Inflammatory lung injury after bronchial instillation of air pollution particles. *Am J RespirCrit Care Med*, **164**, 704–708.

Githiomi J. K. , Kung'u J. B. and Mugendi D. N (2012); Analysis of wood fuel supply and demand balance in Kiambu, Thika and Maragwa districts in central Kenya, *Journal of Horticulture and Forestry*, **4(6)**, 103-110.

Gibson P.G., Simpson, J.L., Chalmers, A.C., *et al*. (2001); Airway eosinophilia is associated with wheeze but is uncommon in children with persistent cough and frequent chest colds. *Am J Respir Crit Care Med*, **164**, 977–981.

Grubb C. (1994); Diagnostic Cytopathology, a Text and Colour Atlas. Churchill Livingstone, London. 65–112.

Godfrey, A.J, Kirangwa Denis, WaiswaDanie and Okia Clement Akais, (2010): Household Firewood Consumption and its Dynamics in Kalisizo Sub-County, Central Uganda. *Ethnobotanical Leaflets*,**14**, 841-855.

Goel, V.L., and Behl, H.N (1996); Fuel wood quality of promising tree species for alkaline soil sites in relation to tree age. *Biomass Bioenergy,* **10**, 57–61.

Goel. V.L, and Behl. H.M (2001); Genetic selection and improvement of hard wood tree species for fuel wood production on sodic soil eith particular reference to Prosopis juliflora, *Biomass and Bioenergy*, **20**, 9-15.

Gold,D.R., Litonjua,A, Schwartz, J., Lovett, E., Larson, A., Nearing, B., Allen, G., Verrier, M., Cherry, R., and Verrier, R., (2000); Ambient pollution and heart rate variability. *Circulation*, **101**, 1267-1273.

Goldemberg, J., T.B. Johansson, A.K.N. Reddy and R.H. Williams, (1988); Energy for a Sustainable World, Wiley-Eastern, New Delhi, 571.

Goldemberg Jose and Thomas B. Johansson (Eds), (1995); Energy As An Instrument for Socio-Economic Development. United Nations Development Programme, New York.

Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams, (2004); A global clean cooking fuel initiative. *Energy for Sustainable Development*, **8(3)**, 5-12.

Gowaz, M., Langer, H., and May, F.E.,(2005); Platelets in inflammation and atherogensis. *Jchin Invest*, **115**, 3378-84.

Gundimeda H, and Köhlin G. (2008); Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence. *Energy Econ*, **30(2)**,517–546.

Hakkila, P, and Kalaja, H., (1983); Ash of biofuels – green wood chips made of denromass from willow and poplars grwon on plantations. (Puu- ja kuorituhkan palauttamisen tekniikka). Folia Forestalia. **552**, 37.

Harada, T., (2001); Time to Ignition, heat release rate and fire endurance time of wood in cone calorimetry test. *Fire and Materials*.**25**, 161-167.

Harris, H. A., (1984); Fuel values of stems and branches in white oak, yellow poplar, and sweet gum. *Forest Products Journal*. **34(3)**, 25-26.

Hartley Sir Harold, (1984); Fuel and Power in 1984. In: Grow Your Own Energy, Michael Cross (Ed). A newscientist Guide, Basil Blackwell Limited, Oxford, JF., 3-7.

He G, Ying B, Liu J, Gao S, Shen S, Balakrishnan K, *et al*., (2005); Patterns of household concentrations of multiple indoor air pollutants in China. *Environ Sci Tech*, **39(4)**, 991–8.

Heinzerling, A.P., Guarnieri, M.J., Mann, J.K., Diaz, J.V., Thompson, L.M., Diaz, A., *et al*., (2016); Lung function in woodsmoke-exposed Guatemalan children following a chimney stove intervention. *Thorax*, **71 (5)**, 421–428.

Hogg J. C. and Van Eeden S. (2009); “Pulmonary and systemic response to atmospheric pollution,” *Respirology*, **14(3)**,336–346.

Hosier, R.H. and J. Dowd, (1987); Household fuel choice in Zimbabwe: An empirical test of the Energy Ladder Hypothesis. *Resources and Energy*, **13 (9)**, 347-361.

Hulscher, W.S., (1995); FAO - Regional Wood Energy Development Programme in Asia, "Misconceptions about Wood Energy", Asian Development Bank Brown Bag Seminar, Manila.

Humbert, M., Sitbon, O. and Simonneau, G. (2004); Treatment of pulmonary arterial hypertension. N Engl J Med 351: 1425–1436.

Hytönen, J., and Nurmi, J(2015); Heating value and ash content of intensively managed stands. Wood Res-Slovak. **60**, 71–82.

IEA (2002); World Energy Outlook, 2002. IEA, Paris.

Ikurekong E.E., Esin J.O. and Mba,A.C.,(2009); Rural Fuel wood Exploitation in Mbo Local Government Area – A Nigerian Coastal Settlement, Ethiopian Journal of Environmental Studies and Management, **2(3)**.

International Energy Agency (IEA), (2014); Energy Balances of OECD Countries and non OECD Countries, Paris.

Ioannis Gravalos , Dimitrios Kateris, Panagiotis Xyradakis, Theodoros Gialamas, Spiros Loutridis, Augoustinos Augousti, Anastasios Georgiades, Zisis Tsiropoulos (2010); A study on calorific energy values of biomass residue pellets for heating purposes, FORMEC 2010 Forest Engineering: Meeting the Needs of the Society and the Environment, Padova – Italy.

Ishii, H., Fujii, T., Hogg, J.C., *et al*., (2004); Contribution of IL-1b and TNF-a to the initiation of the peripheral lung response to atmospheric particulates (PM10). *Am J Physiol Lung Cell Mol Physiol*, **287**, 176–183.

Isik, B., Isik, R.S., Akyildiz, L., Topcu, F., (2005); Does biomass exposure affect serum MDA levels in women? *Inhal. Toxicol*, **17 (12)**, 695–697.

Jiang Leiwen and Brian C. O'Neill, (2003); The Energy Transition in Rural China, International Institute for System Dynamic Analysis, Interim Report IR- 03-070.

Jha, R. K. (1999); Deforestation and Village Life. Mittal Publications. New Delhi.

Jodha, N. S. (1990); Rural common property resources: Contributions and crisis. Economic and Political Weekly, **25 (26)**, A65–A78.

John D Maclay, David A McAllister, Shonna Johnston, Jennifer Raftis, Catherine McGuinnes, Andrew Deans, David E Newby, Nicholas L Mills, William Mac Nee, Increased platelet activation in patients with stable and acute exacerbation of COPD.

José Goldemberg , Thomas B. Johansson, Amulya K.N. Reddy and Robert H. Williams (2004); A global clean cooking fuel initiative, *Energy for Sustainable Development*, 8 **(3)**.

Joseph A.F., and Shadrach O.A(1997); Biomass yield and energy value of some fast growing multipurpose trees in Nigeria. *Biomass and Bioenergy*, **12(6)**, 429-37.

Joshi. V, (1992); Setting up a rural energy database, Final report submitted to Ministry of Non-conventional Energy Sources, New Delhi; TERI.

Joshi, M., and Srivastava, R.K., (2013); Development and performance evaluation of an improved three pot cook stove for cooking in rural Uttarakhand, India. *International Journal of Advanced Research,* **1(5)**, 596-602.

Jungbluth, N., (1995); Restricted Life-cycle Assessment for the Use of Liquefied Petroleum Gas and Kerosene as Cooking Fuels in India, thesis submitted to the University of Berlin, December, available at www.esu-services/download/DA India.

Kakati K. (1999); The singing apes. *Frontline,* **12**: 65–70.

Karekezi, S., and Ranja, T.,(1997); Renewable Energy Technologies in Africa. Zed Books, London.

Kataki. R., and Konwer, D., (2001); Fuel wood characteristics of some indigenous woody species of north-east India. *Biomass and Bioenergy***20**,17–23.

Kauffmann Celine (2005); Energy and Poverty in Africa. Policy Insights No. 8 is derived from the African Economic Outlook 2003/2004, a joint publication of the African Development Bank and the OECD Development Centre. www.oecd.org/dev/africanoutlook.

Kebede B., (2001); Modem Energy and the Urban Poor in Ethiopia – Literature Review and Associated Empirical Analysis. Medium Study Report for the "Energy Services for the Urban Poor" Theme Group. AFREPREN/FWD, Nairobi.

Klasnja B., Kopitovic, S., and Orlovic, S., (2002); Wood and bark of some poplar and willow clones as fuel wood. *Biomass and Energy*.**23**, 427-432.

Krigstin S. G., Wong, B. M., and Roy, D.N., (1993); The contribution of the chemical components in juvenile hybrid Salix spp. to its total energy output. Wood Science and Technology. **27(4)**, 309-20.

Krishnamurthy T (1999); Role of Forests in Environment. *Indian Forester,***1**, 45-54.

Lahiri, T., and Ray, M.R., (2010); Effects of indoor air pollution from biomass fuel use on women's health in India. In Air Pollution; health and environmental impacts, Gujar, B.R., Molina, L.T., Ojha, C.S.P.,Eds; CRC press: USA,135-163.

Laxmi Vijay, Jyoti Parikh, Shyam Karmakar and Pramod Dabrase, (2003); Household energy, women's hardship and health impacts in rural Rajasthan, India: need for sustainable energy solutions. *Energy for Sustainable Development.* **7 (1)**, 50-68.

Leach, G (1987); Household energy in South Asia. International Institute for Environment and Development, London.

Leach, G., (1992); The energy transition, *Energy Policy*, **20(2)**, 116-123.

Lin, J. J. and Lee, L. C (2004); 'Characterization of the concentration and distribution of urban submicron (PM1) aerosol particles', *Atmos. Environ*. **38**, 469–475.

Lindemann, S., Tolley, N.D., Dixon, D.A.,*et al*., (2001); Activated platelets mediate inflammatory signaling by regulated interleukin 1 beta synthesis. *J Cell Bio*.**154**, 485-490.

Mac (2009); Indoor Air Pollution Create Problems for Rural Areas. http://www. lifeofearth. org.

Mahapatra. A.K and Mitchell. C.P (1999); Biofuel consumption, deforestation and farm level tree growing in rural India: Biomass and Bioenergy, **17**, 291- 303.

Mamun M.R.A., Kabir, M.S., Alam, M.M and Islam M.M. (2009) Utilization pattern of biomass for rural energy supply in Bangladesh. *Int. J. Sustain. Crop Prod*. **4(1)**,62-71.

Martinez Alier Juan, (1995); The use of firewood and deforestation, *WISE News Communique.*

Maryam, B., Akor Dewu, Joseph O. Ayo, Andrew R.Collins, Mabrouk, M.M., Alexander, B., Adelaiye and Fatima L.Ciroma., (2012); Comparative study of haematological and cardiorespiratory parameters in women exposed to biomass or missed fuels. *American International Journal of Contemporary Research*, **2(8),** 257-263.

Masera, O.R., Saatkamp, B. D., and Kammen, D. M.,(2000); Energy and health transactions in development: fuel use, stove technology, and morbidity in Jaracuaro, Mexico. *Energy for sustainable Development*,**4(2)**,7-16.

Masera, O.R., Diaz, R., and Berrueta, V., (2005); From cook stoves to cooking systems: the integrated program on sustainable household energy use in Mexico. *Energy for Sustainable Development*, **9**, 25–36. doi:10.1016/ S0973-0826(08)60480-9.

Mavalankar D.V., C.R. Trivedi and R.H. Gray, (1991); Levels and Risk Factors for perinatal Mortality in Ahmedabad, India. *Bulletin of the WHO,* **69 (4)**, 435- 442.

Mc Gean B., Chatterjee M. and Roy, S.B. (1996); Learning to learn: Training and Gender Sensitization in Indian Forest Departments. Village Voices Forest Choices: Joint Forest Management in India, Edited by Poffenberger, M. and B. Mc Gean, Oxford University Press, Delhi.

Md. Khalequzzaman, MichihiroKamijima, Kiyoshi Sakai, Bilqis Amin Hoque and Tamie Nakajima (2010); Indoor air pollution and the health of children in biomass- and fossil-fuel users of Bangladesh: situation in two different seasons. *Environ Health Prev Med*, **15**, 236–243.

Mercado, I.R., Masera, O., Zamora, H., and Smith, K.R., (2011): Adoption and sustained use of improved cook stoves. *Energy Policy*, **39**, 7557–7566. doi:10.1016/j. enpol.2011.03.028.

Michael Jonathan , Simon Saulei1 and Basil Marasinghe (2009); A study on burning characteristics of some preferred fuelwood tree species in Papua New Guinea, webistem.com/psi2009/ output_ directory/cd1/Data/articles/000090.pdf.

Mishra, V.K., Retherford R.D. and Smith, K.R. (1999); Biomass Cooking Fuels and Prevalence of Tuberculosis in India. *Int J Infect Dis,* **3 (3)**, 119-129.

Mishra, V.K, Retherford, R.D and Smith, K.R.(1999);Biomass cooking fuels and prevalence of blindness in India. *J Environ Med*, **1**, 189-199.
Mishra, V.K, . Retherford R.D and Smith, K.R. (1999); Biomass Cooking Fuels and Prevalence of Tuberculosis in India. *Int J Infect Dis,* **3 (3)**, 119-129.
Misra, V., (2003); Effect of indoor air pollution from biomass combustion on prevalence of asthma in the elderly. *Environ Health Perspective*, **111**, 71-78.

M.S.Swaminathan Research Foundation (2011); Chennai, India. Biotechnology Resources Status in India, Working paper.

Mohan, M., Sperduto, R.D. Angra, S.K. Milton, R.C. Mathur R.L. and Underwood, B.A. (1989); India-US case-control study of age-related cataracts. India- US Case-Control Study Group. *Arch Ophthalmol,* **107**, 670-676.

Mohapatra S.P, and Sahoo H.P (2009); Fuel wood burning and its effect on the environment with reference to tribal villages of Bolangir, Orissa, India: *Ecology, Environment and Conservation*, **15(3)**, 513-516.

Mondal, N.K., Bhaumik,R.K.,.Das C.R., Aditya, P., Datta, J.K., Banerjee A., and Das, K., (2013); Assessment of indoor pollutants generated from bio and synthetic fuels in selected villages of Burdwan, West Bengal. *Journal of Environmental Biology*, **34**, 963-966.

Monn C.and Becker S., (1999); Cytotoxicity and induction of proinflammatory cytokines from human monocytes exposed to fine (PM 2.5) and coarse particles (PM10) in outdoor and indoor air. *Toxicol. Appl. Pharmacol*, **155**, 245-252.

Mukae, H., Vincent R., Quinlan K., *et al*., (2001); The effect of repeated exposure to particulate air pollution (PM10) on the bone marrow. *Am J Respir Crit Care Med*, **163**, 201-209.

Mukae Nowak, D.J., Crane, D.E., and Stevens, J.C., (2006); Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening*, **4**, 115-123.

Murali, K.S., U. Shanker, U.R. Shaanker, K.N. Ganeshaiah and K.S. Bawa. (1996); Impact of NTFPs extraction on regeneration, population structure and species composition. *Economic Botany*, **50**, 252–269.

Murali, K.S. and R. Hegde (1996); Sustainable harvest of NTFPs and forest management, pp. 219–223 In: M.P. Shive & R.B. Mathur (eds.), Management of Minor Forest Produce for Sustainability. Oxford and IBH, New Delhi.

NAAQS (2000); Central Pollution Control Board (CPCB), New Delhi, India, Report No. 98: 16-21.

Natarajan I. (1997); Demand forecast for bio-fuels in rural households, pp. 18–191 In: R.C. Maheswari & P. Chaturvedi (eds.) Biomass Energy: Data Analysis and Trends. IEA/OECD, Paris, France.

Nathan Dev, (1996); Woodfuel Interventions with a Gender Base, *Wood Energy News*, **12(1)**, 19.

Namdeo A and Bell M.C (2005); Characteristics and health implications of fine and coarse particulates at roadside, urban background and rural sites in UK. *Environ Int*, **31**,565–573.

Nansior, A., Patanothai, A., Rambo, A.T., and Simaraks, S., (2013): The sustainability of biomass energy acquisition by households in urbanizing communities in Northeast Thiland. *Biomass and Bioenergy*, **52**, 113-121.

NCAER (1985); Domestic Fuel Survey with Special Reference to Kerosene (1978/79) (National Council for Applied Economic Research, New Delhi).

Nellie M. Oduor and Joseph K. Githiomi (2013); Fuel-wood energy properties of Prosopis juliflora and Prosopis pallida grown in Baringo District, Kenya, **8(21)**, 2476-2481.

Nirmal Kumar, J.I., Kanti, P., Kumar, R.N. and Kumar Bhoi, R. (2009); An Assessment of Indian Fuelwood with Regards to Properties and Environmental Impact. *Asian Journal on Energy and Environment*, **10**, 99-107.

Njeru, L.K., (2009); Indoor carbon monoxide emission and particulates produced from combustion of carbon based fuels and their health implications on rural households of Manyatta division, EMBU district, Kenya.ir-library.ku.ac.ke/botstrea/handle/.

Norboo, T., Yahya, M, Bruce, N.G Heady J.A. and Ball, K.P. (1991); Domestic pollution and respiratory illness in a Himalayan village. *Int J Epidemiol*, **20**, 749-757.

Nordenhall, C, Pourazar, J., Blomberg, A., Levin, J.O., Sandstrom, T., and Adelroth, E.,(2000); Airway inflammation following exposure to diesel exhaust: a study of time kinetics using induced sputum. *EurRespir J*, **15**, 1046–1051.

Nunez Rigueira L., Rodriguez Anon, J.A., and Castinciras, J.P., (1996); Calorific values and flammability of forest species in Galicia. Coastal and hillside forest. *Bioresource Technology*. **57**, 283-289.

NWDP (1986); National Sample Survey (NWDP, New Delhi).

Oberdörster, G., Oberdörster, E., and Oberdörster, J. (2005); Nano toxicology: an emerging discipline evolving from studies of ultrafine particles. *Environ Health Perspect*, **113**, 823- 839.

Oduor, N. and Githiomi, J. (2013); Fuel-wood energy properties of Prosopis juliflora and Prosopis juliflora pallida grown in Baringo District, Kenya. *African J. Agric. Res*. **8**, 2476–2481. doi:10.5897/AJAR08.221.

Ogunkunle A.T., *et al*, (2004); Ethnobotanical Study of Fuelwood and Timber Wood Consumption an Replenishment in Ogbomoso, Oyo State, Nigeria.

Oguntoke, O., Opeolu, B. O. and Babatunde, N. (2010); Indoor Air Pollutants and Health Risks among Rural Dwellers in Odeda Area, Southwestern Nigeria. *Ethopian Journal of Environmental Studies and Management*, 3(2).

Olopade C.O, Frank E, Bartlett E, Alexander D, Dutta A, Ibigbami T, Adu D, Olamijulo J, Arinola G, Karrison T, and Ojengbede O (2016); Effect of a clean stove intervention on inflammatory biomarkers in pregnant women in Ibadan, Nigeria: A randomized controlled study. *Environ Int*., **98**, 181-190. doi: 10.1016/j.envint.2016.11.004.

Oluwole, O., Ana, G.R., Arinola, G.O., Wiskel, T., Falusi, A.G., Huo, D., *et al*., (2013); Effect of stove intervention on household air pollution and the respiratory health of women and children in rural Nigeria. *Air Qual. Atmos. Health,* **6 (3)**, 553–561.

Omar D, Oscar P, and Jose M.B.,(1981); Carbon monoxide contamination in dwellings in poor rural areas of Guatemala, *Bull Environ Contam Toxical*, **26**, 24-30.

Orozco Levi M, *et al*., (2006); Wood smoke exposure and risk of chronic obstructive pulmonary disease. *Eur Respir J*. **27(3)**, 542–546.

Osei, W.Y., (1993); Wood fuel and deforestation-answers for a sustainable environment. *J. Environ. Manage*, **37**, 51-62.

Osornio-Vargas, A.R., Bonner, J.C., Alfaro-Moreno, E., Martinez, L., Garcia-Cuellar, C., Ponce-de-Leon Rosales, S., *et al*., (2003); Proinflammatory and cytotoxic effects of Mexico City air pollution particulate matter in vitro are dependent on particle size and composition. *Environ. Health Perspect*, **111 (10)**, 1289–1293.

Ouedraogo, B. (2006); "Household energy preferences for cooking in urban Ouagadougou, Burkina Faso.", *Energy Policy,* **34(18)**, 3787-3795.

Qureshi, K.A., (1994); Domestic smoke pollution and prevalence of chronic bronchitis/asthma in a rural area of Kashmir. *Indian J Chest Dis Allied Sci,* **36**, 61-72.

Oyebanji, F. F , Adeofun, C. O, Adedeji, O. Hρ , Ekpo, U. F, Oguntoke, O, and Ojekunle, O. Z. Assessment of Respiratory Health Impact of Fuel-Wood Utilization on Exposed Rural Women in Odeda, Southwestern, Nigeria, Global Journal of Science Frontier Research **13(4)**,1.

Oyedepo S.O. (2012); Energy and sustainable development in Nigeria; the way forward.*Energy, Sustain Soc,* **2(15)**, 1-7.

Pandey, M.R., (1984); Domestic smoke pollution and chronic bronchitis in a rural community of the hill region of Nepal. *Thorax,* **39**, 337-339.

Pandey M.R., Basnyat., B. and Neupane, R.P. (1988); Chronic Bronchitis and Cor Pulmonale in Nepal, *{monograph),* Mrigendra Medical Trust. Myers, TR., 2000. Paediatric asthma epidemiology: incidence, morbidity and mortality. *Respir Care Clin North Am,* **6**, 1-14.

Pandey M.R., Neupane R.P., Gautam A., and Shrestha I.B. The effectiveness of smoke less stoves in reducing indoor air pollution in rural hill region of Nepal. *Mountain Res Dev,* 10, 313–320.

Pant, D.D. and Singh, S. P., (1987); Energy use patterns and environmental conservation: The central Himalayan case; T. M. Vinod Kumar and Dilip R. Ahuja (Eds.), Rural Energy Planning for the Indian Himalaya. Wiley Eastern Limited, 191 -225.

Parikh, J., (1995); Gender issues in energy policy. *Energy Policy,* **23 (9)**, 745- 754.

Parik, J.(1996); Poverty, environment and development nexus. Human Development Report. UNDP.

Parikh, J., and Laxmi, V., (2000); Biofuels, pollution and health linkages: a survey of rural Tamil Nadu. *Economic and PoliticalWeekly,* **35 (47)**, 4125–4138.

Patrick G. Abbot and Jimmy D (1999); Lowore, Characteristics and management potential of some indigenous ®rewood species in Malawi, *Forest Ecology and Management*, **119**, 111- 121.

Peat, J.K., M. Haby and J. Spiker, (1992); Has the prevalence of asthma increased? Results from two population study conducted at a nine year interval in Busselton, Western Australia. *BMJ,* **305**, 1326-1329.

Perdizet, S., F. Neukirch and J. Cooreman, (1987); Prevalence of asthma in adolescence in various parts of France and its relationship to respiratory allergy manifestations. *Chest,* **91**, 104-106.

Perez, P. and Reyes, J (2002); ‘Prediction of maximum of 24-h average of PM10 concentrations 30 h in advance in Santiago, Chile’, *Atmos. Environ*. **36**, 4555–4561.

Piantadosi, C.A.,(1996); Toxicity of Carbon Monoxide: Hemoglobin vs. Histotoxic Mechanisms, In Carbon Monoxide, Penney, D.G. (Ed.), CRC Press, Boca Raton, FL, 163–180.

Pinto, A.G., Khanna, P., and Pandey C.N., (1985); Gujarat wood balance study 1984. Vadodara: Gujarat State Forest Department.

Poffenberger, M. and Mc Gean, B. (ed.) (1996); Village Choices, Forest Choices: Joint Forest Management in India. Oxford University Press, Delhi.

Pope C.A., III and Dockery,D.W., (1992); Acute health effects of PMIO pollution on symptomatic and asymptomatic children. *Am Rev Respir Dis*, **145**, 1123-1128.

Pope, C.A, III, Verrier R.L., Lovet,t E.G., Larson A.C., Raizenne, M.E., Kanner, R.E., Schwartz, J, Villegas, G.M., Gold, D.R. and Dockery, D.W., (1999); Heart rate variability associated with particulate air pollution. *American heart journal*, **138**, 890-899.

Pope, C.A. III., Richard T. Burnett, George D. Thurston, Michael J. Thun, Eugenia E. Calle, Daniel Krewski and John J. Godleski, (2004); Cardiovascular mortality and long-term exposure to particulate air pollution. *Epidemiological Evidence of General Pathophysiological Pathways of Disease*, http://www.circulationaha.org, DOI: 10.1161/01.CIR.0000108927.80044.7F.

Pope, C.A. III, and Dockery, D. W.,(2006); Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association*, **56**, 709-742.

Pramod Dabrase, Ramachandra, T.V. and Subramanian, D.K. (1997); Domestic energy consumption patterns in Anthragange area of Kolar Taluk, Karnataka, Paper presented at National Environmental Science Academy, XII Annual Conference.

Prapas J, Baumgardner M.E., Marchese A.J., Willson B., De Foort M (2014); Influence of chimneys on combustion characteristics of buoyantly driven biomass stoves, *Energy for Sustainable Development,* **23**, 286–293.

Preventing chronic diseases (2005); a vital investment : WHO global report.

Puyravaud, J. P., Mohandass D. and Chhabra, T. (2003); A rediscovery of Eriochrysis rangacharri C.E.C Fischer (Poaceae) in the Nilgiri Mountains of southern India. Candollea **58**, 97-100.

Rai, S.N. and Chakrabarti, S.K. (2001); Demand and supply of fuelwood and Timber in India. Indian Forester, **127(3)**, 23-29.

Rai, S. N., and Chalmbarti, S. K., (2001); Demand and supply of fuel wood and timber in India. *Indian Forester,* **3**,263-279.

Raiyani, C.V., Shah, S.H. Desai, N.M., Venkaiah, K, Patel, J.S., Parikh D.J. and Kashyap, S.K. (1993); Characterization and problems of indoor air pollution due to cooking stove smoke. *Atmospheric Environment,* **27 (A) (11)**, 1643-1655.

Ramachandra, T.V.,Subramanian, D.K.,Joshi, N.V.,Gunaga, S.V., and Harikantra, R.B., (2000); End use efficiencies in the domestic sector of Uttar Kannada District. *Energy Conversion and Management*, **41(8)**.

Ramachandra,T. V.,(2007); Geospatial mapping of bioenergy potential in Karnataka, India. *Journal of Energy& Environment*, **6**.

Ramakrishnan, P. S., (2003): Linking natural resource management with sustainable development of traditional mountain societies. *Tropical &orog,* **44**, 43-54.

Ramesh, B.R. (2003); Biodiversity conservation and management. *Tropical Ecology,* **44**, 85–91.

Raub J.A., Mathieu Nolf M., Hampson N. B and Thom S. R, (2000); Carbon monoxide poisoning - a public health perspective, *Toxicology*, **145(1)**, 1–14.

Ravindranath, N.H., Somashekar, B.S., and Gadgil, M., (1992); Carbon Emission and Sequestration in Forests: Case Studies for India and China, LBL: 32759 VC-402, Lawrence Berkeley Laboratory, Berkeley, USA.

Ravindranath, N.H., and Hall, D.O., (1995): Biomass, energy and environment: a developing country perspective from India. Oxford: Oxford University Press.

Ravindranath, N. H.,(1997): Energy options for cooking in India. *Energy Policy*, **25(1)**, 63- 75.

Ray, M.R., Basu, C., and Lahiri, T., (2003); Haematological changes and up-regulation of P-selectin expression in circulating platelets of Indian women chronically exposed to emissions from biomass fuels. *Comp Clin Path,***12**, 151–154.

Ray, M.R., Mukherjee, S., Roychoudhury, S., Bhattacharya, P., Banerjee, M., Siddique, S., Chakraborty, S., and Lahiri, T.,(2006); Platelet activation, upregulation of CD11b/ CD18 expression on leukocytes and increase in circulating leukocyte-platelet aggregates in Indian women chronically exposed to biomass smoke. *Human & Experimental Toxicology*, **25**, 627- 635.

Registrar General of India (RGI), 1994. Annual reports 1993-1994. New Delhi: Office of the Registrar General of India.

Reddy, A.K.N., Annecke, W, Blok, K, Bloom, . D, Boardman, B, Eberhard, A. Ramakrishna, J. Wood Q. and Zaida, A.M. (2000); "Energy and social issues". Chapter 2 in Goldemberg, J., *et al*..World Energy Assessment, UNDP/CSD/WEC, United Nations Development Programme, New York, 46-60.

REN21 (2013); Renewable global future report (2013). Paris: Renewable Energy Policy Network for the 21st Century. Available at: http://www.ren21.net/grf. 76 pp.

Roser, D., Asikainen, A., Gjolsjo, S., Jaskelevicius, B., Johansson, D., Jyhlä, P., *et al*., (2003); Wood fuel resources and bottlenecks of utilization in Baltic and Nordic countries. Joensuu, Finland: Finnish Forest Research Institute.

Roughton F.W. and Darling R.C,(1994); Effect of Carbon Monoxide on the Oxyhemoglobin Dissociation Curve, *Am. J. Physiol*, **141**, 17–31.

Roy S., Ray, M.R., Basu, C., Lahiri, P., and Lahiri, T. (2001); Abundance of siderophages in sputum. Indicator of an adverse lung reaction to air pollution. *Acta Cytol*, 45, 958–964.

Sagar, A.D. and Kartha, S. (2007); Bioenergy and Sustainable Development? Annual Review of Environment and Resources, **32**, 131-167.

Saghir and Jamal. (2004); "Energy and poverty: myths, links, and policy issues," Energy Sector Notes, No. 4, Energy and Mining Sector Board, World Bank, Washington DC.

Salvi,S., Blomberg, A., Rudell B., *et al*., (1999); Acute inflammatory responses in the airways and peripheral blood after short term exposure to diesel exposure in healthy human volunteers. *Am J Respir Crit Care Med*, **159**, 702-709.

Sandoval J., Salas J, Martinez Guerra M.L., Gomez A, Martinez C and Portales, A (1993); Pulmonary arterial hypertension and cor pulmonale associated with chronic domestic wood smoke inhalation. *Chest*, **103**, 12-20.

Sawyer, K., Mundandhara, S., Ghio, A. J. and Madden, M. C. (2010); The effects of ambient particulate matter on human alveolar macrophage oxidative and inflammatory responses. *J Toxicol Environ Health A*, **73**, 41-57.

Schwartz, J., Ballester, F., Saez, M., PAcrez Hoyos, S., Bellido, J., Cambra, K., and Arribas, F., (2001); The concentration response relation between air pollution and daily deaths. *Environmental health perspectives*, **109**, 1001.

Sekar, S.A.G. (1999); Impact of Ayyalur interface forestry project- a vegetation analysis at micro level. *Indian Forester*, **22,** 316–319.

Seppo T. Rinne, Edgar J. Rodas, Mikael. Rinne, Joshua M. Simpson, and Larry T. Glickman, (2007); Use of biomass fuel is associated with infant mortality and child health in trend analysis, am. J. Trop. *Med. Hyg*., **76(3)**,585–591.

Shah, (1982); Ecological degradation and future of agriculture in the Himalayas. *Indian Agric Economics*, **37 (1)**, 1-22.

Shailaja, R., (2000); Women, energy and sustainable development. *Energy for Sustainable Development,* **4 (1),** 45-64.

Shanker, U., Murali K.S., Shaanker U.R, Ganeshaiah K.N. and Bawa K. S. (1998); Extraction of non-timber forest products in the forest of Biligiri Rajan Hills, India. 4. Impact on floristic diversity and population structure in a thorn scrub forest. *Economic Botany* **52**: 302–315.

Shaw, R.A., Crahe J., and O'Donell T.V., (1990); Increasing asthma prevalence in rural New Zealand adolescent population: 1975-1989. *Arch Dis Child*, **65**, 1319-1323.

Singh, B., and Khanduja, S.D.(1994); Wood properties of some firewood shrubs of northern India. *Biomass,* **4**, 235–238.

Singh, G., Rawat, G.S and Verma, D. (2010); Comparative study of fuel wood consumption by villagers and seasonal "Dhaba owners" in the tourist affected regions of Garhwal Himalaya, India. *Energy policy*, **38(4)**, 1895-1899.

Singh, S., Gyan Prakash Gupta., Bablu Kumar and Kulshrestha U.C.,(2014); Comparative study of indoor air pollution using traditional and improved cooking stoves in rural households of Northern India. *Energy for Sustainable Development*, **19**, 1-6.

Singhal, R. M., Kumar, S., and Jeeva, V., (2003). Forest and forestry research in India, *Tropical Ecology*. **44**, 55-61.

Sinha, C.S. and Joshi, V. (1994); Rural Energy Planning in India: Designing Effective Intervention Strategies, Energy Policy, **22 (5)**, 13-15.

Sinha, C. S., Shirish Sinha and Veena Joshi,(1998); Energy use in the rural areas of India: setting up a rural energy data base, *Biomass and Bioenergy*, **14(5/6)**, 459-503.

Snoep J.D, Roest M, Barendrecht A.D, de Groot P.G, Rosendaal F.R, and Van der Bom J.G(2010); High platelet reactivity is associated with myocardial infarction in premenopausal women: a population-based case–control study. *J Thromb Haemost*, **8**, 906–13.

Smith, K.R., (1993); Fuel combustion, air pollution exposure, and health: the situation in developing countries. *Annual Review Energy and Environment*, **18**, 529-566.

Smith, K.R, Samet, J.M., Romieu. I., and Bruce, N., (2000); Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax*, **55**, 518-532.

Srivastava, S., (2000); Conflict management in protected areas. *Indian Forester*, **10**, 1128-1135.

Sudha Singh, Gyan Prakash Gupta, Bablu Kumar, and Kulshrestha U.C.,(2014); Comparative study of indoor air pollution using traditional and improved cooking stoves in rural households of Northern India, *Energy for Sustainable Development*, **19**,1–6.

Suwa, T, Hogg, J.C., Vincent, R., Mukae, H., Fujii, T., and Van Eeden, S.F., (2002); Ambient air particulates stimulate alveolar macrophages of smokers to promote differentiation of myeloid precursor cells. *Exp LungRes*, **28**, 1–18.

Tata Energy Research Institute (TERI), (2001); Survey of renewable energy in India, New Delhi: 50pp. (TERI Project Report No. 2000RT45).

Taylor, E.T., and Satoshi Nakai., (2012); The levels of toxic air pollutants in kitchens with traditional stoves in rural Sierra Leone. *Journal of Environmental Protection*, **3**, 1353-1363.

TERI. (2013); TERI Energy Data Directory & Yearbook (TEDDY) 2012/13. TERI Press.

Thomas, E., Wickramasinghe, K., Mendis, S., Roberts, N., Foster, C., (2015); Improved stove interventions to reduce household air pollution in low and middle income countries: a descriptive systematic review. *BMC Public Health*, **15**, 650.

Tian, L., Zhang G., Zhang Q., Moschandreas D.L., Hao J., Lin J. and Lin Y (2008); The impact of kitchen activities on indoor pollution concentrations. *Indoor Built. Environ*, **17**, 377-383.

Tinsae Bahru, Zemede Asfaw and Sebsebe Demissew,(2012); Indigenous knowledge on fuel wood (charcoal and/or firewood) plant species used by the local people in and around the semi-arid Awash National Park, Ethiopia, *Journal of Ecology and the Natural Environment* **4(5)**,141-149.

UNEP (1999); Report on Development and harmonization of environmental standards in East Africa. UNEP, Nairobi Kenya, **2**, 22-28.

UNEP, (2006); Annual report, United nations environment programme **(**2007**).** The 2006 annual report is a summary of UNEP's activities in 2006.

Verma, R.K., Totey N.G. and Gupta. B.N. (1997); Analysis of forest vegetation in the permanent preservation plot of Tamna in Orissa. *Indian Forester*, **11**, 1007– 1016.

Vijay Laxmi, Jyoti Parikh, Shyam Karmakar and Pramod Dabrase, (2003); Household energy, women's hardship and health impacts in rural Rajasthan, India: need for sustainable energy, *Energy for Sustainable Development* 7 (11).

Vinod Mishra (2003); Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe, *Int J Epidemiol*, **32 (5)**, 847-853.

Voipio, R., and Laakso, T., (1992); Chemical composition of the above ground biomass of smallsized trees. (Pienikokoisten puiden maanpäällisen biomassan kemiallinen koostumus). Folia Forestalia, **789**, 22.

Warsco, K., (1994); Conventional fuel displacement by residential wood use. *Forest Products Journal*, **44**, 68-74.

WHO (2002); The world health report 2002; reducing risks, promoting healthy Life. WHO, Geneva, 22-28.

WHO,(2008); Air quality and health: fact sheet, 313.

WHO, (2010); WHO Guidelines for Indoor Air Quality: Selected Pollutants, World Health Organization, Geneva.

Wig, W.L., Guleria J.S. and Bhasin R.C., (1964); Certain clinical and epidemiological aspects of chronic bronchitis as seen in Northern India. *Indian J ChestDis*,**6**, 183-184. Malik, S.K., 1977. Chronic bronchitis in North India. (Communication to Editor). *Chest*, 72, 800.

Wijayatunga, P.D.C., and Attalage, R. A., (2002); Analysis of household cooking energy demand and its environmental impact in Sri Lanka. *Energy Conversion and Management*.**43**, 2213-2223.

Wilson W.E., and Suh H.H.,(1997); Fine particles and coarse particles: concentration relationships relevant to epidemiologic studies, *J Air Waste Manag Assoc.* **47(12)**, 1238-49.

World Bank (2002); India; household energy, indoor air pollution and health. Energy Sector Management Assistance Program (ESMAP), Report No. 261/02. Washington, DC: World Bank.

World Health Organization (WHO), (1997); Health and Environment in Sustainable Development. WHO/EHG/97.8. Geneva.

World Energy Outlook (2006); - FOCUS ON KEY TOPICS.

Xing Yang, Hailong Wang, Peter James Strong, Song Xu 1, Shujuan Liu, Kouping Lu , Kuichuan Sheng, Jia Guo, Lei Che, Lizhi He, Yong Sik Ok , Guodong Yuan, Ying Shen and Xin Chen,(2017); Thermal Properties of Biochars Derived from Waste Biomass Generated by Agricultural and Forestry Sectors, Energies, **10**, 469; doi:10.3390/en 10040469.

Yee J, Sadar M.D, Sin D.D, Kuzyk M, Xing L, Kondra J, McWilliams A, Man SF, Lam S(2009); Connective tissue-activating peptide III: a novel blood biomarker for early lung cancer detection. *J Clin Oncol*, **27**, 2787–2792. doi: 10.1200/JCO.2008.19.4233.

Zeng, W.S.，Shou Zheng Tang，and Qian Hui Xiao (2012); Calorific values and ash contents of different organs of Masson pine (*Pinusmassoniana*) in southern China. *Nature Precedings*, doi:10.1038/npre.2012.6750.1.

Zhang J, Smith K.R, Ma Y, Ye S, Weng X, Jiang F, *et al*., (2000); Greenhouse gases and other airborne pollutants from householdstoves in China: a database for emission factors. *Atmos Environ*, **34**, 4537–4549.

Zhou, H., and Kobzik, L., (2007); Effect of concentrated ambient particles on macrophage phagocytosis and killing of *Streptococcus pneumoniae*. *Am. J. Respir. Cell Mol. Biol.***36**, 460–465.

Zodpey, S.P and Ughade, S.N. (1999); Exposure to cheaper cooking fuels and risk of age related cataract in women. *Ind J Occupational Environ Med*, **3**,159-161.

Zuk M, Rojas L, Blanco S *et al*., (2007); The impact of improved wood-burning stoves on fine particulate matter concentrations in rural Mexican homes. *J Expo Sci Environ Epidemiol*, **17**, 224–232.

Annexure I

Questionnaire

1. Name of the respondent.............................., Male ☐ Female ☐

2. Occupation: ....

3. Literacy: Literate ☐ Illiterate ☐

4. Number of members in the family.

Men ☐ Women ☐ Children ☐ Total ☐

5. Annual income of the family: ....

6. Land holdings at home: Low ☐ Medium ☐ High ☐

7. Types of fuel consumed:

LPG ☐ Kerosene ☐ Firewood ☐ Agricultural residues ☐

Electricity ☐ Solar ☐ Biogas ☐

8. Type of fuel used for cooking:

LPG ☐ Kerosene ☐ Firewood ☐ Agricultural residues ☐

Electricity ☐ Solar ☐ Biogas ☐

9. Type of fuel used for domestic purpose (Heating):

LPG ☐ Kerosene ☐ Firewood ☐ Agricultural residues ☐

Electricity ☐ Solar ☐ Biogas ☐

10. Purpose of utilization: Domestic ☐ Industry ☐

if others specify.............................

11. Sources of firewood: Farmland ☐ Forest ☐

Wood depots ☐ Avenue trees. ☐

12. Types of biomass consumed as fuel.

Firewood ☐ Agricultural residues ☐

Sawdust ☐ Cow dung cakes ☐

13. Reasons for consuming biomass fuel............................

14. Reasons for not consuming LPG and Kerosene...................

15. Sources of biomass fuel.

Natural forest ☐ Village forest ☐

Avenue trees ☐ Wood depots ☐

Private property resources ☐

16. Is firewood is the main source of fuel. Yes ☐ No ☐

17. Reasons for consuming firewood as fuel................

Easily available ☐ Easy to use ☐

Low income ☐ Free of cost ☐

No accessibility of clean fuel ☐

(LPG, kerosene, electricity etc)

18. Time spent for collection of firewood per day ☐ in hrs.

19. Quantity of firewood collection per day ☐ in Kg.

20. Per capita daily consumption of biomass or fire wood fuel for cooking.

Summer ☐ Rainy ☐ winter ☐

21. Firewood collection :

Within the village ☐

Outside the village ☐

22. Distance walked to collect firewood.

Up to 1 km ☐ 1-2km ☐ 2-3km ☐

>3km ☐ if more ☐

23. Time spent for cooking by using firewood or biomass ☐ in hrs.

24. Diversity of firewood species (Mainly)

Sl. No.	Species name	Local name
1.		
2.		
3.		
4.		
5.		

25. Which species they do not prefer/reasons for not preferring.

Sl. No.	Species name	Local name	Reasons
1.			
2.			
3.			
4.			
5.			

26. Types of biomass cook stoves used.

Traditional ☐ Metal (Sawdust/rice husk) ☐

Clay ☐ Improved (Astra stove) ☐

27. Housing pattern.

Chimney without ventilation ☐ Chimney with ventilation ☐

No ventilation & no chimney ☐ Ventilation without chimney ☐

28. Cookstove location in house:

Outside the house ☐

In the living room of the house ☐

In kitchen separated from living room ☐

29. Reasons for opting improved cook stove.

Health problems ☐ Easy to operate ☐

No risk in cycle ☐ High income ☐

No other source ☐

30. Risks and hazards associated with biomass (firewood) energy cycle.

Collection: Pricks ☐ Allergy ☐ Cuts ☐

Fear of wild animals ☐

Transportation: Body ache ☐ Head ache ☐

Processing: pricks ☐ Cuts ☐

Consumption: Eye irritation ☐ Throat irritation ☐

Allergy ☐ Burns ☐

Cough ☐ Head ache ☐

31. Type of fuel likely to be preferred by the persons, if they provided by

LPG ☐ Kerosene ☐ firewood ☐

agricultural residues ☐

32. Any interest in growing of firewood species in the waste lands, if

Plants provided by forestry management ☐

33. Willing to participate in Social forestry programme,

if organized by forestry management. ☐

Signature of Respondent

Int J Energy Environ Eng (2014) 5:95
DOI 10.1007/s40095-014-0095-3

ORIGINAL RESEARCH

Utilization pattern of biomass energy and socioeconomic dimensions associated with Yelandur, Karnataka, India

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Received: 7 November 2013 / Accepted: 18 February 2014 / Published online: 4 April 2014

Abstract Energy is considered as a key factor which determines the economic development in the entire sector of any region. Biomass is one of the primary energy sources in rural areas. The study was carried out to examine the utilization pattern of biomass energy and socioeconomic dimensions associated with rural areas of Yelandur, Karnataka, India. Field studies in these villages covering 645 households were made to collect the data and assess the socioeconomic conditions that govern the biomass utilization pattern for meeting energy requirements. Firewood is the primary energy source (94.78 %) for cooking and heating among these rural folk. Most of them are illiterates (60 %) with 28.96 % of them having a meagre income. Traditional biomass stoves are used predominantly. The study shows that there is a positive correlation ($R^2 = 0.98$) between the households size and volume of firewood consumption. The study has revealed that the firewood fuels are the dominant source of energy for cooking and heating purposes.

Keywords Biomass · Firewood · Resources · Households · Socioeconomic · Utilization pattern

Introduction

One essential component of rapid economic and social development is energy. It plays an important role in the socioeconomic development of any country. To achieve development goals through energy, it requires better knowledge of how people make decisions about their energy use [1]. Biomass is one of the primary sources of energy for about 2.4 billion people in developing countries [2].

Biomass resources include wood and wood wastes, agricultural crops and their residues, municipal solid waste, animal waste, waste from food processing, aquatic plants and algae [3]. It is mainly used as fuel sources for cooking and heating purposes in the rural households. The biomass fuels in its various forms have been recognized as a useful and cost-effective alternative source of energy. It has advantages over fossil fuels due to various environmental concerns. These fuels do not contribute to the carbon dioxide levels of atmosphere and thus prevent aggravation in global warming [4].

Biomass fuel is found to be a suitable energy source that can be converted to higher energy content fuels through direct combustion, thermochemical conversion, or biochemical conversion processes [5]. Briquette (combination of two or more biomass fuels in a compressed form) is used as an alternative fuel to coal, which is easy to transport and has better handling, storage and very efficient energy sources [6]. Calorific value determines the energy efficiency of the firewood. There are numerous indicators of fuel efficiency. These may include the indoor air pollution, greenhouse effects (e.g. deforestation, CO_2 emission during production, conversion and consumption), etc. [7].

More than 70 % of Indian population lives in rural areas and they satisfy 80 % of their energy needs only from the fuelwood collected from forests and nearby sites [8]. Cooking fuels in the rural areas of India are predominantly unprocessed biofuels, such as fuelwood, crop residues and animal dung [9–12]. In Karnataka, India, considering all types of energy sources and sector-wise consumption reveals that, traditional fuels such as firewood (43.60 %),

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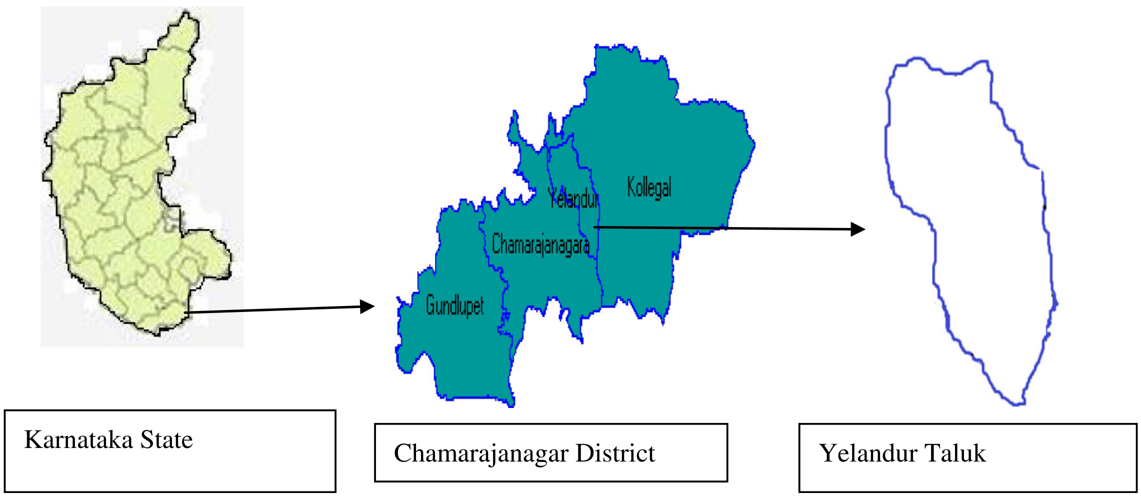

Fig. 1 Study area

agro-wastes (8.20 %) and cow dung (1.40 %) account for 53.20 % of total energy consumption [13].

The usage of biomass energy is greatly influenced by socioeconomic factors such as household size, income level, poor household access to clean energy sources and low household standard. There is a strong correlation between a household family size and the volume of firewood consumed per day [14].

The present paper highlights the utilization and consumption pattern of biomass energy resources and the socioeconomic factors associated with the villages of Yelandur taluk.

Study area: The study was carried out in Yelandur taluk of Chamarajanagar district, Karnataka, India (Fig. 1). It is located between 11°42′–12°5′ North latitude and 76°57′–77°09′ East longitudes with an area of 266.34 km^2 comprising a population of about 82170. The investigation was undertaken in four villages: A.Devarahalli, Malarapalya, Uppinamole and Katanvadi.

Methods

Based on the stratified simple random sampling technique [15], four villages were selected for collecting primary data on several household parameters through door-to-door interview. Six hundred and forty-five households were surveyed to gather the information.

The survey was conducted to identify and quantify the biomass fuel resource, consumption patterns and to record their daily demand. A questionnaire was designed to get the data on the comprehensive picture of socioeconomic conditions, energy use pattern, housing characteristics and cooking behaviours. Energy usage included information on consumption of biomass fuels and commercial fuels for cooking and heating, sources of procurement of cooking fuel, time and effort involved in procurement, and energy demand. The statistical package for social sciences (Statistical Analysis in Social Science, SPSS version 16.0 Chicago SPSS Inc.) was used for the analysis of data. The data obtained from the survey were pooled and analysed by employing analysis of variance (ANOVA), followed by Tukey's honest significant difference (HSD) mean range test for knowing the significance at $P > 0.05$ level (probability at greater than 0.05 level or 5 %).

Results and discussion

The survey data indicated that the majority of the respondents were farmers by primary occupation and half of the fuelwood demand is satisfied through their own farmland sources. Socioeconomic characteristics of the surveyed households are given in Table 1. Among the respondents (645), the numbers of females are 59 % and males 41 %; while illiterates are 60 % and literates are only 40 %. This indicates that the literacy level is low in these villages.

The households are categorized into four classes based on the landholdings such as landless or low (below 1 acre), middle (1–5 acre) and high (above 10 acre). Among these, the landless account for 27.37 %, the households with 1–5 acre account for 39.43 %, below 1 acre account for 34.94 % and above 10 acre account for only 1.79 % of households. On an average of four villages, only 4 % of the population of households have annual income above Rs. 50,000, while 31 % around Rs. 10,000, 40 % less than Rs. 10,000 and the remaining has no fixed income. Interestingly, our survey reveals that 12.84 % of households of A.Devarahalli, 16.68 % of Malarapalya, 45.74 % of Uppinamole and 40.58 % of households of Katanvadi have no

Table 1 Socioeconomic characteristics of the household

Name of the villages	Total number of households	Respondent (*n*)		Respondent (%)		Land holdings (%)				Income (%)			
		Male	Female	Literate	Illiterate	Low (<1 acre)	Medium (1–5 acre)	High (>10 acre)	Nil	Low (1,000–10,000 Rs/year)	Medium (10,000–50,000 Rs/year)	High (>50,000 Rs/year)	Nil
A.Devarahalli	48	21.00 ± 1.00^{a}	29.00 ± 1.00^{a}	36.83 ± 1.61^{a}	61.83 ± 1.61^{a}	38.67 ± 1.15^{a}	44.20 ± 0.69^{a}	1.00 ± 1.73^{a}	19.20 ± 0.69^{a}	37.17 ± 1.04^{a}	47.30 ± 0.61^{a}	4.67 ± 1.53^{a}	12.84 ± 0.35^{a}
Malarapalya	182	103.67 ± 1.53^{b}	77.66 ± 2.52^{b}	52.00 ± 2.00^{b}	49.00 ± 1.00^{b}	$36.00 \pm 1.73^{b,c}$	50.00 ± 1.73^{b}	2.01 ± 1.72^{a}	14.20 ± 1.91^{b}	56.37 ± 1.47^{b}	28.87 ± 1.03^{b}	2.67 ± 1.52^{a}	16.68 ± 0.54^{b}
Uppinamole	200	48.33 ± 1.53^{c}	151.67 ± 1.53^{c}	31.20 ± 0.72^{b}	69.13 ± 1.03^{b}	39.67 ± 1.15^{b}	21.80 ± 1.04^{b}	1.67 ± 2.89^{a}	42.07 ± 2.54^{c}	28.37 ± 1.10^{b}	27.53 ± 0.50^{b}	3.00 ± 2.65^{a}	45.74 ± 0.41^{c}
Katanvadi	215	95.00 ± 1.00^{d}	120.00 ± 1.00^{d}	39.30 ± 0.61^{c}	61.03 ± 1.00^{c}	25.41 ± 0.72^{c}	41.73 ± 2.83^{c}	2.47 ± 2.19^{a}	34.00 ± 17.87^{d}	38.90 ± 1.15^{c}	20.00 ± 2.00^{c}	5.73 ± 1.42^{a}	40.58 ± 0.40^{d}
Overall	–	67.00 ± 35.41	94.58 ± 48.14	39.83 ± 8.04	60.25 ± 7.61	34.94 ± 6.01	39.43 ± 11.19	1.79 ± 1.95	27.37 ± 11.77	40.20 ± 10.80	30.93 ± 10.60	4.02 ± 2.04	28.96 ± 15.02
F value	–	2.756	3.184	124.093	147.941	82.93	143.465	0.240	176.834	292.494	287.565	1.814	4.510
Sig@0.05 level	–	S	S	S	S	S	S	NS	S	S	S	NS	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant, *NS* not significant

a,b,c,d Values containing same superscripts are not significant at 0.05 level

annual income as they are working as labourers in other farmlands on daily wages and below the poverty line. Because of this, the majority of them cannot afford to buy cleaner energy sources and therefore, they depend much on easily available and economically feasible fuelwood resources.

In these four villages, firewood is the dominant source of energy for their daily requirement as present in Table 2. The villagers mainly use biomass fuel for cooking and heating purposes. The sources of energy available include fuelwood and agricultural residues, kerosene and liquid petroleum gas (LPG).

They use different types of energy sources such as firewood and agricultural residues as traditional energy types while LPG and kerosene as modern energy types. Among these energy types, the biomass energy is the one which is mainly used as the primary sources of energy. The results of the investigation show that all the households of Uppinamole village use firewood as their main energy source. Usage of LPG as energy source is relatively less in these villages. Firewood is the primary and major fuel (94.78 %) for cooking in all these villages, followed by agricultural residues (78.87 %), kerosene (55.85 %) and LPG (35.83 %). In all these villages, kerosene is also used for lighting purposes.

The trees commonly used as fuelwood in these villages are shown in Table 3. Among these, the most preferred species are *Coccus nucifera*, *Prosopis juliflora*, *Acacia auriculiformis*, *Ficus benghalensis* and *Randia uliginosa* as they can be easily grown in the farmlands. The species with higher wood density are preferred as fuel because of their high energy content per unit volume and their slow burning property [16, 17]. The villagers do not prefer to use the wood of *Pongamia pinnata* and bamboo species as they find that the cooking requires consumption of more quantity of wood. Moreover, they experienced less heat being generated by the wood of these species which also burn out rapidly. The villagers also do not prefer to use the wood of *Coccinia grandis* as it emanates bad smell during combustion.

It is established that firewood with heavy weight, less moisture and ash content gives more heat [18]. The ash content in timber is an important feature that affects the fuel capacity. High ash content makes it less desirable as fuel [19–21], because a considerable part of the volume cannot be converted into energy [22]. If the firewood is not properly dried up, it gives more smoke and less heat while burning, because it requires 3.21 MJ (Mega Joules) of energy to remove 1.0 kg of moisture present in the fuel [23]. Wood makes an outstanding fuel as it is 99 % flammable if it is completely dry [24, 25].

Gathering fuelwood involves a lot of hardship of walking for long distances and carrying head loads of

Table 2 Types of energy sources used as fuel by villagers (%)

Energy sources	Name of the villages			
	A.Devarahalli	Malarapalya	Uppinamole	Katanvadi
LPG	45.83 ± 1.04[a]	41.64 ± 0.92[a]	6.55 ± 0.08[a]	49.30 ± 0.85[a]
Kerosene	88.40 ± 0.95[b]	40.03 ± 0.26[a]	58.95 ± 1.53[b]	36.01 ± 0.61[b]
Firewood	97.43 ± 0.56[c]	97.58 ± 0.75[b]	99.34 ± 0.60[c]	84.78 ± 1.55[c]
Agricultural residues	69.52 ± 0.83[d]	87.54 ± 0.83[c]	78.83 ± 0.36[d]	79.58 ± 0.65[d]
F value	2.086	5.025	6.683	1.691
Sig @ 0.05 level	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

Table 3 Commonly used firewood species

S. no.	Scientific name of the species	S. no.	Scientific name of the species
1	*Acacia nilotica* (Gobli)	11	*Acacia leucophloea* (Bili Jali)
2	*Ficus benghalensis* (Ala)	12	*Prosopis juliflora* (Gobli)
3	*Albizia amara* (Chujli)	13	*Albizia lebbeck* (Dodda Baage)
4	*Azadirachta indica* (Bevu)	14	*Morinda tinctoria* (Muddi)
5	*Acacia ferruginea* (Banni)	15	*Pongamia pinnata* (Honge)
6	*Ficus infectoria* (Basari)	16	*Acacia auriculiformis* (Jaali)
7	*Persea Americana* (Benne)	17	*Sapindus laurifolius* (Antuvala)
8	Randia *uliginosa* (Kare)	18	Coccinia grandis (Tonde)
9	*Mammea suriga* (Surgi)	19	*Citrus maxima* (Chakotta)
10	*Terminalia arjuna* (Matti)	20	*Anogeissus latifolia* (Bejjalu/ Dindiaga)
11	*Coccus nucifera* (coconut)	21	*Terminalia paniculata* (Matti)

Name in the parenthesis represents the local name of the species

Table 4 Time and effort involved in collection of firewood

Name of the villages	Distance travelled for collection (km)	Time spend/day for collection (h)	Firewood collection/day (kg)
A.Devarahalli	2.85 ± 0.50[a]	2.99 ± 0.10[a]	19.47 ± 0.64[a]
Malarapalya	2.54 ± 0.03[a]	3.64 ± 0.40[b]	19.00 ± 0.43[a]
Uppinamole	3.23 ± 0.09[b]	3.58 ± 0.11[b]	22.53 ± 0.47[b]
Katanvadi	2.56 ± 0.10[c]	3.68 ± 0.10[b]	21.83 ± 0.21[b]
Overall	2.79 ± 0.30	3.47 ± 0.31	20.71 ± 1.62
F value	55.77	37.57	41.97
Sig @ 0.05 level	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c] Values containing same superscripts are not significant at 0.05 level

fuelwood that can cause health disorders in individuals (mostly women and children) [26]. Table 4 gives the details of efforts made and time spent in gathering of fuelwood. The average walking distance to collect fuelwood is about 2.79 km. They spend time around three and half hours to collect an average of 20.71 kg of fuelwood per day. Almost, these efforts are done by women only, as they are the ones mainly associated with gathering, processing and transportation of fuelwood. Very few people are getting the firewood from wood depots, but most of them are collecting from their own farmland, village forest and nearby natural forest. Crop residues are generally collected from their own farmland.

Fuelwood consumption with seasonal variations in the studied villages is shown in Table 5. The minimum per capita consumption of fuelwood recorded during summer season in Malarapalya and Uppinamole villages is 0.82 kg per capita per day. The consumption of fuelwood is more in the rainy season because of its usage in domestic purposes such as water heating. In all the seasons, per capita consumption of firewood is more in the Katanvadi village as compared to other villages.

The overall survey data shows that, there is a positive correlation between the household family size and the volume of firewood consumed per day (Fig. 2). A strong correlation ($R^2 = 0.99$) is found between the household size and firewood consumption in rainy season, followed by winter ($R^2 = 0.98$) and summer ($R^2 = 0.97$) seasons.

Table 5 Seasonal and per capita consumption of firewood in the villages of Yelandur

Name of the villages	Daily consumption of firewood (kg)					
	Household consumption/day			Per capita consumption/day		
	Summer	Rainy	Winter	Summer	Rainy	Winter
A.Devarahalli	3.58 ± 0.08[a]	4.81 ± 0.96[a]	4.40 ± 0.23[ab]	0.87 ± 0.06[a]	1.08 ± 0.01[a]	0.97 ± 0.02[a]
Malarapalya	3.52 ± 0.16[a]	5.05 ± 0.13[a]	4.19 ± 0.16[a]	0.82 ± 0.03[a]	1.16 ± 0.02[a]	0.94 ± 0.01[a]
Uppinamole	4.14 ± 0.11[b]	5.38 ± 0.15[b]	4.79 ± 0.90[bc]	0.82 ± 0.03[a]	1.05 ± 0.02[b]	0.96 ± 0.02[a]
Katanvadi	4.26 ± 0.14[b]	5.83 ± 0.52[b]	4.91 ± 0.08[c]	0.84 ± 0.02[a]	1.17 ± 0.02[b]	0.98 ± 0.02[a]
Overall	3.88 ± 0.36	5.27 ± 0.41	4.57 ± 0.33	0.84 ± 0.04	1.12 ± 0.06	0.96 ± 0.02
F value	27.95	44.96	14.59	1.28	43.59	2.15
Sig @ 0.05 level	S	S	NS	NS	S	NS

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant, *NS* not significant

[a,b,c] Values containing same superscripts are not significant at 0.05 level

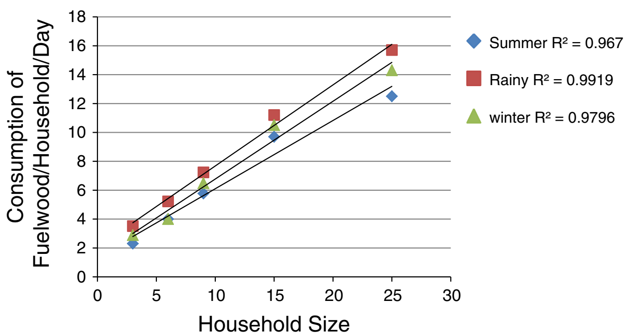

Fig. 2 Correlation coefficient between household size and fuelwood consumption in different seasons

Table 6 Household size and average firewood consumption in different seasons

Household size	Average firewood consumption/household/day (kg)		
	Summer	Rainy	Winter
1–3	2.3	3.51	2.89
4–6	3.81	5.22	4
7–9	5.77	7.23	6.48
10–15	9.7	11.2	10.5
16–25	12.3	15.7	14.3

The volume of firewood used per day varied from 2.3 to 12.3 kg in summer, 3.51–15.7 kg in rainy and 2.8–14.3 kg in winter seasons, depending on the size of the household (Table 6).

It was observed that, the households use different types of stoves for cooking as shown in Table 7. Four types of stoves (Traditional, Clay, Metal and ASTRA) are used in these villages. The majority of the households use clay stoves for biomass fuels. This kind of stoves has no chimney and consists of three bricks plastered with mud to form U shape with one side left open to feed fuel. People do not use single type of fuel, but they use multiple fuels or mixed fuels in these stoves. The use of clay stove is found to be highest in Uppinamole village (77.83 %). Only 35.73 and 37.67 % of people are using ASTRA stove for cooking purpose in Malarapalya and Katanvadi, respectively.

The usage of traditional cookstove was found to be more in A.Devarahalli (57.38 %). The traditional stove is made up of three stones, which requires more firewood. The loss of heat is more in the traditional stoves as compared to other stoves. The traditional stoves using fuelwood have low thermal efficiencies of about 14 % [4]. Metal stoves are used by less number of people. In Uppinamole village, 40.29 % of the households have separate kitchens for cooking while 15.58 % cook outside the house (Table 8). 46.37 % of the people use cookstoves without chimney and proper ventilation. On an average, 68 % of households of the other three villages possess separate kitchens for cooking. It is observed that, on an average, only 45.96 % of households have cooking stoves with chimney and good ventilation for cooking. Thus, from the above data it can be predicted that the people in these villages are more prone to firewood smoke-related health problems.

ASTRA stove is found to be beneficial for the villagers as it is helpful in minimizing the deposition of particulate matter and consumption of firewood. Although, many of them are aware of problems associated with biomass smoke, they still depend on biomass cooking stoves. However, household size, level of income and cost of cleaner energy sources are the governing factors for the households to make the choice of advanced cooking stoves. There are many other factors which determine the fuel choice, e.g. culture, social desirability and security of supply [27, 28]. During our interaction most of the people

Table 7 Type of cookstoves used by households of villages

Villages	Types of cookstoves used by households (%)			
	Traditional	Clay	Metal	ASTRA
A.Devarahalli	57.38 ± 0.74^{a}	34.80 ± 0.4^{a}	6.27 ± 0.25^{ab}	3.43 ± 0.35^{a}
Malarapalya	8.30 ± 0.26^{b}	46.90 ± 1.32^{b}	17.70 ± 1.23^{a}	35.73 ± 0.64^{b}
Uppinamole	8.60 ± 0.35^{b}	77.83 ± 1.59^{b}	8.67 ± 0.51^{b}	10.87 ± 0.76^{c}
Katanvadi	4.53 ± 0.31^{c}	47.30 ± 1.25^{c}	7.87 ± 0.70^{c}	37.67 ± 0.83^{d}
Overall	19.70 ± 22.79	51.71 ± 16.64	10.13 ± 4.70	21.93 ± 15.70
F value	9.090	671.36	136.73	2.002
Sig @ 0.05 level	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

Table 8 Housing pattern and location of cookstoves in the households of villages

Villages	Housing pattern				Location of cookstove		
	Chimney without ventilation (%)	Chimney with ventilation (%)	No chimney and no ventilation (%)	Ventilation without chimney (%)	Outside of the house (%)	Living area (%)	Separate kitchen (%)
A.Devarahalli	3.32 ± 0.12^{ab}	47.17 ± 0.25^{a}	28.11 ± 0.18^{a}	22.31 ± 0.36^{a}	6.20 ± 0.35^{a}	28.38 ± 0.36^{a}	66.41 ± 0.41^{a}
Malarapalya	3.14 ± 0.16^{a}	53.54 ± 0.61^{b}	17.41 ± 0.40^{b}	19.61 ± 0.72^{b}	5.54 ± 0.47^{a}	33.39 ± 0.36^{b}	62.51 ± 0.44^{b}
Uppinamole	2.44 ± 0.41^{b}	30.04 ± 0.56^{c}	22.37 ± 0.33^{c}	46.37 ± 0.51^{c}	15.58 ± 0.50^{b}	45.54 ± 0.47^{c}	40.29 ± 0.25^{c}
Katanvadi	13.51 ± 0.44^{c}	53.10 ± 0.36^{c}	13.37 ± 0.33^{d}	10.44 ± 0.00^{d}	8.45 ± 0.39^{c}	16.44 ± 0.41^{d}	76.35 ± 0.42^{d}
Overall	5.60 ± 4.79	45.96 ± 9.96	20.32 ± 5.77	24.68 ± 13.87	8.94 ± 4.17	30.94 ± 10.91	61.39 ± 13.78
F value	824.86	1.665	1.191	2.874	338.402	2.651	4.590
Sig @ 0.05 level	S	S	S	S	S	S	S

Mean ± standard deviation followed by same superscript letters within column is not significant, when subjected to Tukey's mean range test @ 0.05 level

S significant

[a,b,c,d] Values containing same superscripts are not significant at 0.05 level

have expressed their willingness to shift from using the traditional stove to improved stoves, if they are provided with improved stoves.

Conclusions

The study has revealed that the firewood fuels are the dominant source of energy for cooking and heating purposes. Village forests and farmlands are the chief sources of firewood for them, which are at stake. For many households, switching away from traditional biomass is not feasible in the short term. Training and awareness to use improved stoves such as ASTRA stoves can promote the better way of using biofuel sources. The analyses show that the inertia of household cooking energy preferences is due to poverty factors such as low income, low standing of living which in most cases meant no access to external or internal cooking facilities, large households, high cooking frequency of certain meals, etc. Also there are economic, technical, social and traditional constraints to complete switching to cleaner fuels. The determination of calorific values and analysis of smoke constituents of these fuelwood species can further help in identification of suitable species for better utilization of biomass energy. Recommendation of such species to be grown in wastelands of their vicinity helps in promoting self-sustenance and can reduce the pressure on natural forests for fuelwood species.

Acknowledgments Author A. G. Devi Prasad is thankful to UGC, New Delhi for financial assistance to major research project. Author Komala H.P. is thankful to DST, New Delhi for awarding JRF.

Conflict of interest The authors declare that they have no competing interests.

Author's contributions All authors have been involved in drafting the manuscript and approved the final manuscript.

Referencess

1. Kowsari, R., Zerriffi, H.: Three dimensional energy profiles. Energy Policy **39**, 7505–7517 (2011)
2. Karekezi, S., Kithyoma, W.: Bioenergy and agriculture: promises and challenges. Bioenergy and the poor. In: 2020 Vision for Food, Agriculture and the Environment. International Food Policy Research Institute (2006)
3. Gavrilescu, M., Chisti, Y.: Biotechnology—a sustainable alternative for chemical industry. Biotechnol. Adv. **23**, 471–499 (2005)
4. Ravindranath, N.H., Hall, D.O.: Biomass, Energy and Environment: A Developing Country Perspective from India. Oxford University Press, Oxford (1995)
5. Sofer, S., Zaborsky, O.: Biomass Conversion Processes for Energy and Fuel. Plenum Press, New York (1981)
6. Panwar, V., Prasad, B., Wasewar, K.L.: Biomass residue briquetting and characterization. J. Energy Eng. **137**(2) (2011). Technical papers. doi:10.1061/(ASCE)EY.1943-7897.0000040
7. Guta, D.D.: Assessment of biomass fuel resource potential and utilization in Ethiopia: sourcing Strategies for renewable energies. Int. J. Renew. Energy Res. **2**(1), 131–139 (2012)
8. Bhattacharya, P.K.: Biomass power generation and environment impact. ENREE **78**(9), 1078–1092 (2005)
9. Branes, D.F., Sen, M.: Energy strategies for rural India. Evidence from six States, UNDP/World bank energy sector management assistance program (2000)
10. Parikh, J., Smith, K., Laxmi, V.: Indoor air pollution: a reflection on gender bias. Econ. Polit. Wkl. **34**(9), 539–544 (1999)
11. Saxena, N.C.: Fuelwood—issues for the Ninth Plan. Wood Energy News **44**(2), 3–4 (1999)
12. Sinha, C.S., Venkata, R.P., Joshi, V.: Rural energy planning in India: defining effective intervention strategies. Energy Policy **22**(5), 403–414 (1994)
13. Ramachandra, T.V., Subramanian, D.K., Joshi, N.V., Gunaga, S.V., Harikantra, R.B.: Domestic energy consumption patterns in Uttara Kannada District, Karnataka State, India. Energy Convers. Manag. **41**, 775–831 (2000)
14. Godfrey, A.J., Denis, K., Daniel, W., Akais, O.C.: Household firewood consumption and its dynamics in Kalisizo Sub-Country, Central Uganda. Ethnobotanical Leaflets **14**, 841–855 (2010)
15. Joon, V., Chandra, A., Bhattacharya, M.: Household energy consumption pattern and socio-cultural dimensions associated with it: a case study of rural Haryana, India. Biomass Bioenergy **33**, 1509–1512 (2009)
16. Singh, B., Khanduja, S.D.: Wood properties of some firewood shrubs of northern India. Biomass **4**, 235–238 (1984)
17. Goel, V.L., Behl, H.N.: Fuelwood quality of promising tree species for alkaline soil sites in relation to tree age. Biomass Bioenergy **10**, 57–61 (1996)
18. Chettri, N., Sharma, E.: A scientific assessment of traditional knowledge on firewood and fodder values in Sikkim, India. Forest Ecol. Manag. **257**, 2073–2078 (2009)
19. Kataki, R., Konwer, D.: Fuelwood characteristics of indigenous tree species of north-east India. Biomass Bioenergy **22**, 433–437 (2002)
20. Jain, R.K., Singh, B.: Fuelwood characteristics of selected indigenous tree species from central India. Bioresour. Technol. **68**(3), 305–308 (1999)
21. Kumar, R., Pandey, K.K., Chandrashekar, N., Mohan, S.: Effect of tree-age on calorific value and other fuel properties of Eucalyptus hybrid. J Forest Res. **21**, 514–516 (2010)
22. Joseph, A.F., Shadrach, O.A.: Biomass yield and energy value of some fast growing multipurpose trees in Nigeria. Biomass Bioenergy **12**, 101–106 (1997)
23. Roth, C.: Micro gasification: cooking with gas from biomass. 1st ed. Eschborn: GIZ HERA Poverty-Oriented Basic Energy Service, p. 100 (2011)
24. Hiil, A.F.: Economic Botany—A Textbook of Useful Plants and Plant and Plant Products. 2nd edn, p. 560. McGraw-Hill Book Company, Inc., New York (1952)
25. Kochhar, S.L.: Economic Botany in the Topics, 2nd edn, p. 604. Macmillan India Limited, New Delhi (1998)
26. Laxmi, V., Parikh, J., Karmakar, S., Dabrase, P.: Household energy, women's hardship and health impacts in rural Rajasthan, India: need for sustainable energy solutions. Energy. Sustain. Dev. **7**(1), 50–68 (2003)
27. Davis, M.: Rural household energy consumption: the effects of access to electricity—evidence from South Africa. Energy Policy **26**(3), 207–217 (1998)
28. Barnett, A.: Energy and the fight against poverty. Department for International Development (Dfid), Livelihood Sector Report, UK (2000)

International Journal of Applied
and Natural Science (IJANS)
ISSN(P): 2319-4014; ISSN(E): 2319-4022
Vol. 4, Issue 6, Oct -Nov 2015, 1-12

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BIOMASS ENERGY CONSUMPTION AND ITS UTILIZATION PATTERN BY THE TRIBES OF BILIGIRI RANGANA (BR) HILLS, KARNATAKA, INDIA

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ABSTRACT

Biomass energy is a prime requirement for meeting the domestic needs among the rural folk of developing countries. Sources for biomass energy are mainly derived from wood, agricultural residues and cow dung cakes. This study investigated the consumption and utilization pattern of firewood species among the six tribes of Biligiri Rangana hills. Field exploration, identification and sample collections of the wood species were made. The calorific value and the ash content of the firewood species were determined. The paper examined the socio-economic status, housing pattern and type of cook stoves used by the tribes. The paper highlights the calorific value, ash content of firewood species and housing pattern of the tribes.

KEYWORDS: Biomass, Calorific Value, Chimney, Cook Stoves, Households, Ventilation

INTRODUCTION

Energy is one of the major factors which influence the economic development of any country. It is a fundamental and strategic tool even to attain the minimum quality of life. Total world energy use rises from 524 quadrillion British thermal units (Btu) in 2010 to 630 quadrillion Btu in 2020. Renewable energy and nuclear power are the world's fastest growing energy sources, each increasing by 2.5 percent per year [1].

It is estimated that forty percent of the global population relies on combustion of solid biomass fuel to fulfil some or all of their household energy needs [2]. Total primary energy consumption of biomass reached approximately 57 exajoules (EJ) in 2013 [3]. The majority of the people burn biomass in traditional, inefficient cooking structures that produce dangerous indoor air environments, resulting in several millions deaths per year [4].

Biomass energy resources vary geographically, and are not uniformly distributed [5,6]. The use of biomass energy is dependent on various factors, such as geographical location, land use patterns, preferences, cultural and social issues. Income distribution patterns also contribute to variations in biomass energy use, with poorer regions relying on traditional forms of biomass, and industrialized regions using more modern biomass energy technologies [7, 8].

Heavy reliance on biomass fuels in developing countries has raised global concerns over both environmental consequences such as forest degradation, soil erosion and the adverse health consequences of indoor air pollution generated by burning wood, animal dung or agricultural residues [9]. The impact of firewood collection on forest degradation and its relationship with rural livelihood has been largely debated, the issue receiving varying attention over time [10, 11].

Traditional biomass energy is a local energy source, which is readily available to meet the energy needs of a significant proportion of the population – particularly the poor in rural areas of the developing world. Traditional biomass energy is low cost and it does not require processing before use [12]. In India, biomass fuels dominate rural energy consumption patterns, accounting for over 80 per cent of total energy consumed. Fuel wood is the most preferred and dominant biomass source, accounting for 54 percent of biomass fuels used in India. Crop residues, agricultural biomass, and livestock dung are also being used. One of the important features of rural energy use is the dependence on locally available biomass resources [13].

Wood fuels are the world's most important form of non-fossil energy burning [14]. Fuel wood, dung cakes and crop residues still remain the primary household fuels with their share in household energy consumption well above 50% in most Asian countries [15]. Roughly 275 million poor rural people in India-27 percent of the total population depend on forests for at least part of their subsistence and cash livelihoods, which they earn from fuel wood, fodder, poles, and a range of Non-Timber Forest Products (NTFP) such as fruits, flowers and medicinal plants [16].

By 2020, the total supply of fuel wood from forests and other source is estimated to be 44.4 million metric tonnes (Ministry of Environment and Forest, Government of India). An estimated 139 million metric tonnes of fuel wood was harvested above the sustainable supply in 2006 [17].

The plant biomass can be utilized directly as a solid fuel or after its conversion into liquid biofuel, such as bioethanol or biodiesel [18]. The heating value of biomass is an indication of the energy chemically bound in it, which is converted into heat energy through a combustion process. The heating value is the most important property of a fuel which determines its energy value. The design and control of a biomass combustor depend strongly on the heating value of a biomass fuel [19].

Improved biomass technologies (IBTs) contribute to more efficient and environmentally sound use of biomass energy. Improved cook stoves, for instance, are designed to reduce heat loss, decrease indoor air pollution, increase combustion efficiency and attain a higher heat transfer [20, 21]. This helps in sustainable use and management of biomass energy sources.

The present study, therefore, was aimed at examining the household firewood consumption and its utilization pattern in BR hills, Chamrajanagar district, Karnataka.

MATERIALS AND METHODS

Study Area

Biligiri Rangana hills (BR hills), is a hill range situated in Yelandur taluk, Chamarajanagar district of south-eastern Karnataka (Figure.1). It lies in the coordinates of 77°–77°16'E, 11°47'–12°9'N, covering an area of 540 sq km. The hills are located at the eastern most edge of the Western Ghats and support diverse flora and fauna in view of the various habitat types supported. The district is known for its forest resources and has a high population of forest-dwellers. The proportion of Scheduled Tribes in this district is 11 % [22] and about 12,500 Soligas (2403 families) in 57 forest villages called Podus, are dwelling inside the Sanctuary [23,24,25]. Among these, Yarkanagadde podu, Hos podu, Muttugadagadde podu, Seegebetta podu, Kalyani podu and Manjigundi podu were investigated for assessing the biomass energy utilization.

Based on the stratified simple random sampling technique [26], households were selected for collecting data on several household parameters through door to door interview. The survey was conducted to identify and quantify the biomass fuel resource and consumption patterns. A questionnaire was designed to get the data on energy use pattern, housing characteristics, cook stoves used, types of biomass fuels, commercial fuels used for cooking and heating, sources of procurement of cooking fuel, time and effort involved in procurement. The data collected from the survey were subjected to statistical analysis using ANOVA, followed by Tukey's Honest Significant Difference (HSD) mean range test for knowing the significance at P > 0.01 level (Probability at less than 0.01 levels).

Determination of Calorific Value:

One gram of wood powder was oven dried to constant weight and burned in an oxygen bomb calorimeter (Model AC 350) for determining calorific value.

Determination of Percentage of Ash Content:

2 g of firewood samples was put into an oven dried moisture free crucibles, and heated up to 575±25^0 C in muffle furnace for 3 hr [27]. All analyses were done in duplicate and the results were expressed on as is basis.

$$\% \text{ of Ash content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

RESULTS AND DISCUSSIONS

The data obtained from the survey of the households revealed that, biomass is the major energy source utilized by the people for cooking and heating purposes. To meet their energy requirements, 98% households are exclusively depending on forests while the remaining households depend on both forests and farm lands. Only the households of Yarakangadde (7.41%), Muttuagada gadde (2.1%) and Seegebetta (3%) are using liquid petroleum gas (LPG) as energy source in addition to firewood.

The results show that, there is 100% utilization of firewood in all the podus except Muttugada gadde podu (98%). The usage of commercial energy sources such as kerosene (8.62%) and LPG (4.17%) for cooking is very low in these villages mainly because of low income. They use these only during an emergency need. From the results of the survey (Table-1) it is evident that firewood is the major energy source for households as compared to LPG or kerosene.

The commonly used plant species as firewood are listed in Table 2. Among these species, *Embelia ribes, Garcinia indica, Gmelina arborea, Litsea glutinosa, vitex negundo and Elaeocarpus ganitrus* are used as biomass fuel occasionally during festivals of local diety. They consider these species to be sacred and hence utilize only during such occasions. One of those species, *Elaeocarpus ganitrus*, commonly known as Rudrakshi, is a threatened species in North Eastern region of India and is declining at an alarming rate due to deforestation. Further, due to ethnic importance, nuts are collected in huge quantities from the forest floor causing depletion of its seed bank [28]. Another species *Embelia ribes*, a medicinal woody climber, belonging to Myrsinaceae, commonly known as false black pepper or vidanga is reported to be vulnerable in the Western Ghats of Tamil Nadu and Karnataka states of India and is at a lower risk in Kerala state of peninsular India [29].

The households avoid some species such as *Radermachera xylocarpa*, *Viraxylem indicum, Stereospermum personatum and Nothapodytes nimmoniana* to be utilized as they have experienced more smoke, spark and bad smell during combustion of wood.

The findings of calorific value and percentage of ash content of ten plant species are shown in Table 3. Calorific value is one of the most important parameter to assess the combustibility of fuel wood. Calorific value is defined as the amount of heat that gives when it is burnt with excess of oxygen, at a given pressure and temperature. The results of the present investigation shown that, the heating (calorific) value of the samples ranged between 3042 cal/gm and 6713 cal/gm. The highest heating value was obtained in *Meliosma pinnata* (6713cal/gm) followed by *Gmelina arborea* (6134 cal/gm), while *Ixora arboria* shows lowest heating value (3042 cal/gm). The ash content is the remaining inorganic part of wood matter that cannot be combusted.

A high ash content of a plant part makes it less desirable as fuel, because a considerable part of the volume cannot be converted into energy [30]. It is one of the important parameters which directly affect the quality of fuel. A biomass having low ash content is considered better feedstock [31, 32]. Our studies have shown that there is significant difference between the calorific value and ash content of the firewood species. By conventional criteria, this difference is considered to be extremely statistically significant (The two tailed p value is less than 0.0001). The analysis shows that among ten firewood species *Acacia catechu* has highest ash content (5.8%) followed by *Litsea glutinosa* (4.2%). *Grewia tiliifolia* has the lowest ash (1.3%) content, followed by *Cantunaregam spinosa* (1.7%), *Melotus tetracoccus* (1.8%) and *Ixora arboria* (1.95%).

The average time spent, distance travelled, quantity of firewood collection and consumption per day by the households in all the podus are shown in Table-4. The households spent 2.5 hr per day on an average to collect the firewood. The people used to travel a distance of 2.3 to 3.6 kms in search of firewood. They used to gather the fallen branches of trees. The quantity of firewood collected ranges from 19.7 kg to 25 kg per day. It is recorded that the consumption of firewood /household/day ranges from 4.42 kg to 6 kg. The results have shown that all the podus use more or less same quantity of firewood.

In our investigation it is recorded that the households are using various types of biomass cook stoves for cooking (Table 5). Traditional type of biomass cook stove require more firewood than necessary, but some studies have shown that the efficiency of a three-stone cooking stoves can be quite high if the fire is closely tended and managed [33]. While cooking in the traditional stoves, people use small and well dried wood pieces. Bembridge and Tarlton [34] reported the preference of smaller pieces of firewood by gatherers as it tends to suit the traditional method of making fires. Among the other types of cook stoves used by podus, clay stove is mostly preferred by households. Highest usage of clay stoves was seen among Yarkanagadde podu (92.59%) while it was used to a lesser extent by Manjigundi podu (13.3%). The improved cook stove ASTRA is used only by Hosa podu (6.9%), Muthugagadde (12.5%) and Sigebetta podu (8.82%).

It is reported that the ASTRA improved stove had the highest PHU (Percent heat utilization-34%), considerably higher than the traditional stove fuelled with firewood (14.2%) [35]. The concentrations of aerosol components and gases in the indoor air during the operation of improved cooking stoves (ICS) were found to be lower as compared to traditional cooking stoves (TCS) [36].

Within developed regions, nearly every solid fuel combustion system that operates within an indoor environment includes a ventilation system to transport combustion products outside of the user envelope. In underdeveloped regions this feature has been met with resistance. Many end-users prioritize stove cost and fuel savings over indoor air quality and chimneys are sometimes perceived to add cost to a stove without saving fuel [37]. Chimney is indeed capable of being advantageous or deleterious to a stove system depending on design, implementation, and maintenance [38].

The results present herein show that, the housing pattern in the villages very poor without proper ventilation and chimney etc., (Table 6). Also there are no separated kitchens for cooking among the inhabitants of Kalyani and Manjigundi podu (Table 7). The households of Manjigundi podu used to cook exclusively in living room (100%). However, some of the households of other podus use the cook stove outside their living room (3.7% to 21.43%).

Among the houses of Kalyani podu, there are no chimney and ventilation. This results in poor combustion efficiency caused by a low air to fuel ratio (i.e., reduced combustion air inflow or high fuel loads) leading to a substantial increase in particulate emissions as well as the organic carbon content of the emissions [39]. Opening the door and window in a kitchen lowered the particulate matter (PM) 1-hour concentrations between 93 and 98% compared to the closed kitchen, and the carbon monoxide (CO) 1 hour concentrations were 83 to 95% lower [40]. Chimney plays an active role in the performance of a stove by influencing the overall air-to-fuel ratio and subsequently the production of carbon monoxide [38]. People dwelling in such areas where particulate emissions and organic carbon content are more become more prone for health hazards. Small-scale combustion of biomass fuels, however, results in the emission of various pollutants including repairable particulates and carbon monoxide; unvented stoves operating in unventilated kitchens can result in pollutant concentrations that are harmful to the cook and anybody else present during the cooking period [41, 42].

The results of the present work confirm the existence of a greater dependency of the biomass energy of the rural folk of BR hills. Thirty eight arboreal species are being randomly used as fuel wood in the villages without knowing the heat efficiency. Most of the households use traditional cook stoves and cannot afford to use alternate improved cookstoves owing to poor per capita income. Poor house design and lack of awareness about indoor air pollution have become dearer for their health hazards.

ACKNOWLEDGMENTS

Author A.G. Devi Prasad is thankful to UGC, New Delhi for financial assistance to major research project. Author Komala H.P. is thankful to DST, New Delhi for awarding JRF.

REFERENCES

1. International Energy Outlook 2013, U.S. Energy information administration; 2013.
2. Bonjour S, Adair-Rohani H, Wolf J, Bruce N.G., Mehta S, Pruss-Ustun A, et al.Solid fuel use for household cooking: Country and regional estimates for 1980-2010. Environ Health Perspect 2013; 121(7): 784-90.
3. Renewable energy policy network for the 21st century (Global Status Report-2014), RE 21, secretariat, Paris, France; 2014.
4. Bruce N, Dora C, Krzyzanowski M, Adair-Rohani H, Morawska L, Wangchuk T. Air Qual Clim Change 2013; 47:32.
5. International Energy Agency. World Energy Outlook, 2002. IEA, Paris;2002.
6. Reddy, K.N., Williams, R.H. and Johansson T.B. Energy After Rio: Prospects and challenges. United Nations Development Programme, New York;1997.
7. Leach, G., 1992. The Energy Transition, Energy Policy February 1992.

8. Hall, D.O. Biomass Energy. Energy Policy 1991; 19 (10).

9. Bruce, N., Perez-Padilla, R., Albalak, R. Indoor Air Pollution in Developing Countries: a Major Environmental and Public Health Challenge. Bulletin of the World Health Organization 2000; 78(9): 1078-92.

10. Arnold, M., Köhlin, G., Persson, R., & Sheperd, G. Fuelwood Revisited: What Has Changed in the Last Decade? Center for International Forestry Research Occasional Paper 2003; 39: Jakarta.

11. Arnold, M., Köhlin, G., Persson, R. Woodfuels, Livelihoods, and Policy Interventions:Changing Perspectives. World Development 2006; 34(3): 596-611.

12. Hall, D.O., Mao, Y.S., Biomass and Coal in Africa. Zed Books Ltd, London; 1994.

13. M S Swaminathan Research Foundation Chennai, India. Bioenergy Resource Status in India, Working paper May 2011.

14. FAO. The State of the World's Forests. Food and Agricultural Organization, Rome, Italy; 1999.

15. Lefevre T et al, "status of wood energy data in Asia", paper presented at IEA's First biomass workshop, February 1997, Paris.

16. World Bank. India Unlocking Opportunities for Forest-Dependent People in India. Report 2005; No. 34481-19. IN.

17. Bahuguna, V.K., Mitra K, Capitran D., Sargal S.. (Eds.). Root to Canopy: Regenerating Forests through Community-State Partnerships. Delhi: Winrock International and Commonwealth Forestry Association. CIFOR (Centre for International Forestry Research) news online, Fuel wood and the poor in the last decade, 2004[http://www.cifor.cgiar.org/Publications/Corporate/NewsOnline/NewsOnline33/fuelwood.htm].

18. Bacovsky D, Dallos M, Worgetter M. Status of 2nd generation biofuels demonstration facilities; A report to IEA bioenergy task, 2010;39: 1-126.

19. Tajana Kricka, Neven Voca, Tea Brlek Savic, Nikola Bilandzija, Sttjepan Sito. Higher heating values estimation of horticultural biomass from their proximate and ultimate analysis data. Journal of Food, Agriculture and Environment 2010; 8(3&4): 767-771.

20. Karekezi, S, Ranja, T. Renewable Energy Technologies in Africa. Zed Books, London; 1997.

21. Masera, O.R., Saatkamp, B. D., Kammen, D. M. Energy and health transactions in development: fuel use, stove technology, and morbidity in Jaracuaro, Mexico. Energy for sustainable Development 2000; 4(2):7- 16. International Energy Initiate, India.

22. GoK. Karnataka Human Development Report - 2005. Department of Planning and Statistics. Bangalore: Government of Karnataka;2005.

23. Kothari, A., Palande, S, Wani, M. Forest Fires and The Ban on NTFP Collection in Biligiri Rangaswamy Temple Sanctuary, Karnataka. Pune: Kalpavriksh ;2007: p15.

24. Madegowda, C. Traditional knowledge and conservation. Economic and Political Weekly 2009; 44 (21): 65-69.

25. Setty R. S., Bawa K., Ticktin T., Gowda C. M. Evaluation of a Participatory Resource Monitoring System for Nontimber Forest Products: the Case of Amla (Phyllanthus spp.) Fruit Harvest by Soligas in South India. Ecology and Society 2008; 13(2).

26. Joon V., Chandra A., Bhattacharya M. Household energy consumption pattern and socio- cultural dimensions associated with it: a case study of rural Haryana, India. Biomass Bioenergy 2009; 33: 1509-1512.

27. Soumya Sasmal, Vaibhav V. Goud, Kaustubha Mohanty. Characterization of biomass available in the region of North – East India for production of biofuels. Biomass and Bioenergy 2012; 45: 212-220.

28. Khan M.L., Putul Bhuyani, Tripathi R.S. Regeneration of Rudraksh (*Elaeocarpus granitrus* Roxb., a threatened tree species: germination strategies. International Journal of Ecology and Environmental Sciences 2003; 29:255-260.

29. Ravikumar, K, Ved, D. K. Red listed medicinal plants of conservation concern in Southern India. Foundation for Revitalization of Local Health and Traditions, Bangalore; 2000. http:// envis.frlht.org.in.

30. Joseph A.F., Shadrach O.A. Biomass yield and energy value of some fast growing multipurpose trees in Nigeria. Biomass and Bioenergy 1997; 12(6): 429-37.

31. Kataki R, Konwrer D. Fuel wood characteristics of some indigenous woody species of northeast India. Biomass and Bioenergy 2001; 20: 17-23.

32. Channiwala S.A., Parikh P.P. A unified correlation for estimating HHV of solid, liquid and gaseous fuels. Fuel 2002; 81: 1051-63.

33. Peter A. Dewees. The Woodfuel Crisis Reconsidered: Observations on the Dynamics of Abundance and Scarcity. World Development 1989; 17(8): 1159-1172.

34. Bembridge, T.J., Tarlton, J.E. Wood fuel in Ciskei: a headload study. South African Forest Journal 1990; 154: 88–93.

35. Ravindranath N. H. Energy options for cooking in India. Energy Policy 1997; 25(1): 63- 75.

36. Sudha Singh, Gyan Prakash Gupta, Bablu Kumar and Kulshrestha U.C. Comparative study of indoor air pollution using traditional and improved cooking stoves in rural households of Northern India. Energy for Sustainable Development 2014; 19:1-6.

37. Smith K. R. Econ Pol Wkly 1989; 24: 517-22.

38. Prapas J., Baumgardner M.E., Marchese A.J., Willson B., Defoort M. Influence of chimneys on combustion characteristics of buoyantly driven biomass stoves, Energy for sustainable development 2014; 23: 286-293.

39. Schmidl C, Luisser M, Padouvas E, Lasselsberger L, Rzaca M, Ramirez-Santa Cruz C, et al. Particulate and gaseous emissions from manually and automatically fired small scale combustion systems. Atmos Environ 2011; 45(39):7443-54.

40. Kelley Grabow, Dean Still, Sam Bentson. Test kitchen studies of indoor air pollution from biomass Cook stoves. Energy for sustainable development 2013;17: 458-462.

41. Smith, K. R. Biqfire Lr. Air Pollution. and Health: A Glohnl Review. Plenum, New York; 1987.

42. Ramakrishna, J., Durgaprasad, M. B., Smith, K. R. Cooking in India: the impact of improved stoves on indoor air quality. Environment International 1989; 15: 341-352.

APPENDIES

Table 1: Types of Energy Sources Used as Fuel by Villagers (%)

Name of the Villages	Types of Energy Sources			Source of Firewood
	LPG	Kerosene	Firewood	Forest
Yarkanagadde	7.41	7.41	100	100
Hosa	0.00	3.45	100	96.6
Muttugadagadde	2.10	2.10	98	98
Sigebetta	3.00	23.50	100	100
Kalyani	0.00	0.00	100	92.9
Manjigundi	0.00	7.00	100	100
Mean	2.09	7.24	99.67	98.0
Variance	8.45	71.54	0.67	7.6
Std. Dev	2.91	8.46	0.82	2.76
Std. Err.	1.19	3.45	0.33	1.13
Tukey HSD Test: HSD[.05]=7.61; HSD[.01]=9.65				
LPG vs Kerosene			P > 0.01	Non- significant
LPG vs Firewood			P < 0.01	Significant
LPG vs Forest as source			P < 0.01	Significant
Kerosene vs Firewood			P < 0.01	Significant
Firewood vs Forest as source			P > 0.01	Non- significant

Table 2: Commonly Used Plant Species as Firewood

Sl.No	Name of the Species	Local Name	Family
1	*Grewia tiliifolia*	Dadsu	Tiliaceae
2	*Kydia calycina*	Bende	Malvaceae
3	*Anogeissus latifolia*	Bejjalu	Combretaceae
4	*Catunaregam spinosa*	Kaare	Rubiaceae
5	*Celtis tetrandra*	Kakkeelu	Ulmaceae
6	*Eriolaena quinquelocularis*	Katale	Sterculiaceae
7	*Bischofia javanica*	Neelalu	Euohorbiaceae
8	*Terminalia paniculata*	Holuge	Combretaceae
9	*Mitragyna parviflora*	Ettaga	Rubiaceae
10	*Phylanthus emblica*	Naayi nelli	Euohorbiaceae
11	*Ixora arboria*	Goraga	Rubiaceae
12	*Memecylon umbellatum*	Chiguri	Melastomataceae
13	*Aporusa lindleyana*	Kana anse	Euohorbiaceae
14	*Melotus tetracoccus*	Jeneraku	Euohorbiaceae
15	*Persea americana*	Benne mara	Lauraceae
16	*Acacia catechu*	Kaggali	Mimosoideae
17	*Cassia fistula*	Kakke	Fabaceae
18	*Helicteres isora*	Kowri	Sterculiaceae
19	*Bauhinia malabarica*	Kallu muttuga	Caesalpiniodeae
20	*Lantana camara*	Roja	Verbenaceae
21	*Lantana indica*	Roja	Verbenaceae
22	*Elaeocarpus tuberculatus*	Kende	Elaeocarpaceae
23	*Meliosma pinnata*	Mustaka	Sabiaceae

24	*Canarium strictum*	Dhoopa	Burseraceae
25	*Boswellia serrate*	Naadu Dhoopa	Burseraceae
26	*Trichilia connaroides*	Kari hittina mara	Meliaceae
27	*Nothapodytes nimmoniana*	Moragadi	Lcacinaceae
28	*Radermachera xylocarpa*	Udi mara	Bignoniaceae
29	*Stereospermum personatum*	Paadri	Bignoniaceae
30	*Bridelia retusa*	Sirhonne	Phyllanthaceae
31	*Diospyros melanoxylon*	Toopura	Ebenaceae
32	*Diospyros motana*	Jagala ganti	Ebenaceae
33	*Embelia ribes*	Vayu vilanga	Myrsinaceae
34	*Garcinia indica*	Punar puli	Clusiaceae
35	*Gmelina arborea*	Kooli	Verbenaceae
36	*Litsea glutinosa*	More	Lauraceae
37	*Vitex negundo*	Lakki patre	Verbenaceae
38	*Elaeocarpus ganitrus*	Rudrakshi	Erythroxylaceae

Table 3: Calorific Value and Ash Content of Firewood Species

Serial No.	Name of the Species	Calorific Value (cal/gm)	Normalized Data for cal/gm (%)	Ash (%)
1	*Grewia tiliifolia*	5172	9.90	1.30
2	*Cantunaregam spinosa*	5908	11.29	1.70
3	*Ixora arboria*	3042	5.80	1.95
4	*Mallotus tetracoccus*	5071	9.69	1.80
5	*Acacia catechu*	4986	9.53	5.80
6	*Cassia fistula*	4897	9.36	3.05
7	*Meliosma pinnata*	6713	12.83	2.30
8	*Nathapodytes nimmoniana*	5348	10.22	2.10
9	*Gmelina arborea*	6134	11.72	2.33
10	*Litsea glutinosa*	5071	9..69	4.20

NOTE: The two tailed p value is less than 0.0001.

Table 4: Time and Effort Involved in Collection of Firewood by Tribes

Name of the Villages	Distance Travelled (km)	Time Spent /collection (hr)	Firewood Collection/Day (kg)	Firewood Consumption/ Household/Day (in kg)
Yarkanagadde	3.60	3.63	25.0	4.42
Hosa	2.80	1.93	19.70	4.67
Muttugadagadde	2.89	2.26	19.80	4.58
Sigebetta	2.20	2.32	22.20	5.17
Kalyani	2.80	2.36	19.60	6.0
Manjigundi	3.30	2.53	21.70	4.67
Mean	2.93	2.51	21.33	4.93
Variance	0.19	0.29	3.73	0.29
Std. Dev.	0.44	0.53	1.93	0.54
Std. Err.	0.17	0.20	0.73	0.20
Tukey HSD Test: HSD[.05]=1.56; HSD[.01]=1.97				
Distance travelled vs Time spent/ Collection			P > 0.01	Non- significant
Distance travelled vs Firewood collection/day			P < 0.01	Significant
Distance travelled vs Firewood consumption/ household/day			P < 0.01	Significant
Time spent/ Collection vs Firewood collection/day			P < 0.01	Significant

Time spent/ Collection vs Firewood consumption/ household/day	P < 0.01	Significant
Firewood collection/day vs Firewood consumption/ household/day	P < 0.01	Significant

Table 5: Type of Stoves used by Households of Villages for Cooking

Name of the Villages	Types of Cookstoves Used by the Households (%)			
	Traditional	Metal	Clay	Astra
Yarkanagadde	14.80	3.70	92.59	0.00
Hosa	17.24	3.45	72.40	6.90
Muttugadagadde	58.30	2.10	25.00	12.50
Sigebetta	58.82	2.94	29.41	8.82
Kalyani	78.57	0.00	21.42	0.00
Manjigundi	86.66	0.00	13.30	0.00
Mean	52.40	2.03	42.35	4.70
Variance	916.93	2.78	1035.5	29.78
Std. Dev.	30.28	1.67	32.18	5.46
Std. Err.	12.36	0.68	13.14	2.23
Tukey HSD Test: HSD[.05]=36.1; HSD[.01]=45.75				
Traditional stove vs Metal stove			P < 0.01	Significant
Traditional stove vs Clay stove			P > 0.01	Non- significant
Traditional stove vs Astra stove			P < 0.01	Significant
Metal stove vs clay stove			P < 0.05	Significant
Metal stove vs Astra stove			P > 0.01	Non-significant
Clay stove vs Astra stove			P < 0.05	Significant

Table 6: Housing Pattern in the Households of B.R. Hills

Name of Villages	Housing Pattern			
	Chimney without Ventilation (%)	Chimney with Ventilation (%)	No Chimney and no Ventilation (%)	Ventilation without Chimney (%)
Yarkanagadde	7.40	29.63	33.33	29.63
Hosa	0.00	6.89	37.93	55.17
Muttugadagadde	0.00	12.70	53.19	34.04
Sigebetta	0.00	11.76	85.29	2.94
Kalyani	0.00	0.00	100	0.00
Manjigundi	0.00	0.00	93.33	6.67
Mean	1.23	10.16	67.18	21.41
Variance	9.13	121.05	857.21	476.72
Std. Dev.	3.02	11.00	29.28	21.83
Std. Err.	1.23	4.49	11.95	8.914
Tukey HSD Test: HSD[.05]=31; HSD[.01]=39.29				
Chimney without ventilation vs Chimney with ventilation			P > 0.01	Non- significant
Chimney without ventilation vs No chimney and no ventilation			P < 0.01	Significant
Chimney without ventilation vs Ventilation without chimney			P >0.01	Non- significant
Chimney with ventilation vs No chimney and no ventilation			P < 0.05	Significant
Chimney with ventilation vs Ventilation without chimney			P > 0.01	Non-significant
No chimney and no ventilation vs Ventilation without chimney			P < 0.05	Significant

Table 7: Location of Cook Stoves in the Households of B.R. Hills

Name of Villages	Location of Cook Stove		
	Outside of the House (%)	Living Area (%)	Separate Kitchen (%)
Yarkanagadde	3.70	59.25	37.03
Hosa	17.24	72.41	10.34
Muttugadagadde	10.42	77.08	12.50
Sigebetta	2.94	79.41	17.64
Kalyani	21.43	78.57	0.00
Manjigundi	0.00	100	0.00
Mean	9.29	77.79	12.92
Variance	73.95	173.94	188.85
Std. Dev.	8.60	13.74	34.31
Std. Err.	3.51	5.384	5.61
Tukey HSD Test: HSD[.05]=31; HSD[.01]=39.29			
Outside of the house vs Living area		P < 0.01	Significant
Outside of the house vs Separate kitchen		P > 0.01	Non- significant
Living area vs Separate kitchen		P < 0.01	Significant

Karnataka **Chamarajanagar District** **B.R. Hills**

Figure 1: Study Area

International Journal of
Research in Chemistry and Environment
Available online at: www.ijrce.org
ISSN 2248-9649

Research Paper

Assessment of Indoor Air Pollutants Generated from Energy Sources in Rural Households of Chamarajanagar Taluk

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(Received 30th November 2015, Accepted 15th December 2015)

Abstract: *Most of the rural households in India use biomass for cooking and heating purposes. The biomass combustion emit huge amount of pollutants which causes harmful effects on environment and on human health. The present study was conducted to assess the level of indoor air pollutants during cooking in rural households. The investigation was carried out in 50 randomly selected rural households of Chamarajanagar taluk that use biomass, kerosene and LPG as cooking fuels. The concentration of CO and CO_2 were measured by using battery operated CO and CO_2 meter which works on NDIR method. The sampling of suspended particulate matter was done by gravimetric method using handy sampler 821. The particulate matters were collected on micro fiber filter paper which is subjected to morphological analysis by SEM. The recorded mean concentration of CO (46.67 ppm) for traditional cook stove was higher than the WHO standard (35ppm). The results have shown that the emission of CO, CO_2 and SPM concentrations were more for biomass fuels as compared to kerosene and LPG fuels. The suspended particulate matters were found to be spherical, angular, cluster and irregular in shapes. The study has shown that utilization of biomass fuels under poorly designed cook stove is the main factor responsible for increase of indoor air pollutants.*

Keywords: Biomass, Indoor air pollutants, Cook stove, Suspended particulate matter, SEM.

Introduction

Biomass (wood, charcoal, animal dung and agriculture residues) is the primary source of fuels used by poor households in developing countries who can hardly afford other fuel types (kerosene, liquefied petroleum gas-LPG, electricity) [1]. It is the only source which produces a lot of pollutants that are harmful for human health and also have effects on climate change [2]. In various developing countries wood stove emission is the main source of kitchen related indoor air pollution [3]. It has been estimated that biomass fuels on combustion release at least 50 times more noxious pollutants than LPG [4]. Among the solid bio-fuels wood contribute maximum indoor air pollutants than carbon cake [5].

Biomass fuels are traditionally burnt in simple stoves with poor combustion efficiency, under poor ventilation conditions. This often results in emission of smoke that contains several health deteriorating substances at varying concentrations which can pose threat to humans. Biomass and coal smoke contain a large number of pollutants including particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide (mainly from coal), formaldehyde, and polycyclic, organic matter, including carcinogens such as benzo[a] pyrene [6,7]. It was made known that aerosols are common class of indoor air pollutants, and that they represent serious health risks from indoor air pollution [8]. About 1.5 million deaths around the world are attributed to exposure to smoke from biomass fuels [9]. Indoor air quality has became an issue of public concern because individual spend most of their time in indoor and airtight buildings increase the probability for accumulation of indoor generated pollutants [10].

Latest Global Burden of Disease (2012) reports 3.5 million premature deaths per year from HAP (household air pollution) and another 0.5 million premature deaths from ambient air pollution originating from households[11]. Excessive exposure to these emissions is associated with several adverse health effects, especially for women and children [12-16].

The concentrations of indoor air pollutants originating from the burning of solid fuels depend on a number of factors such as fuel type, housing characteristics and cook stove. Depending on cooking activities, the extent of pollution can vary between days and within the day [6, 17]. Keeping these points in view, this present study was undertaken to estimate indoor air pollutants such as CO, CO_2 and suspended particulate matter (SPM) generated from biomass, kerosene and LPG fuels used by the rural households.

Material and Methods

In the present investigation, 50 households were randomly selected and monitored in Chamarajanagar taluk, Chamarajanagar district of Karnataka. It lies between longitude 76^0 48'-76^0 59' and latitude 11^0 15'-11^0 59', covering an area of 1226.67 Sq. kms. Before starting the instrumental measurement, a questionnaire survey was made to collect the information regarding kitchen pattern and type of stoves (LPG, Kerosene, Clay and Astra) used for cooking purposes. Indoor air sampling of CO, CO_2 and SPM was done for a period of 1 hour during cooking with different fuel types [18]. Samplers were placed within the breathing zone of the cook according to standard protocol. In biomass using households, women usually performed cooking in sitting position on the floor. On the other hand LPG users generally cooked in standing position and therefore, the monitors were placed accordingly at a height of 4 feet and 3 feet away from the stove [19]. The concentration of CO and CO_2 was measured by portable CO (NDIR method, Model HTC-CO-1) and CO2 meter (NDIR method, Model GCH-2018).

APM 821(Envirotech) handy sampler was used for sampling of SPM. The pre-weighed glass micro-fibre filter paper of 25mm diameter was placed in the filter cassette of the cyclone head. The flow rate of 1.5 L/min is set in the pump. The filter paper was reweighed after sampling for final weight. The concentration of SPM was calculated by using following equation,

Concentration of SPM ($\mu g/m^3$) = $(W_2 - W_1)*10^3 / V$

Volume of air sampled, $V = (F_1 + F_2) / 2 * T$

Where,
W_1= Initial weight of filter paper
W_2= Final weight of filter paper
F_1=Initial flow rate in m^3/min
F_2=Final flow rate in m^3/min
T = Time period in minutes

Determination of morphology (shape and sizes) of suspended particulate matter was performed using Scanning Electron Microscopy (SEM-ZEISS). The SPM samples were collected over filter paper (one by forth of filter paper) and examined under SEM. SEM is a method for high resolution surface imaging. Its advantages over light microscopy are greater magnification and much larger depth of field. Different elements with different surface topography emit different quantity of electrons due to which the contrast in a SEM micrograph is representative of the surface topography and distribution of elemental composition on the surface [20]. During scanning, electrons are emitted from the surface. The number of emitted electrons determines the brightness of the image on the monitor. In this analysis, the emitted electrons were recorded by a detector. Electrons high sensitivity enables this detector to produce an "element contrast picture". Heavy elements and compounds reflect more electrons than light elements, and thus appear lighter in the image [21].

Results and Discussion

The study involves the assessment of indoor pollutants such as CO, CO_2 and SPM and morphological characterization of suspended particulate matter. The investigation has shown that people are using different types of energy fuels such as biomass, kerosene and LPG for cooking purpose based on their income status.

Table 1 presents the concentration of indoor air pollutants (CO, CO_2 and SPM) generated during cooking for different fuels in the households. On an average the concentration of carbon monoxide was found to be 2, 16 and 20 ppm for LPG, kerosene and biomass fuels respectively. The maximum concentration of CO was recorded for biomass fuels (60 ppm) as compared to kerosene (24 ppm) and LPG (3 ppm) fuels. The World Health Organization's one hour average CO standard is 35 mg/m^3 or nearly 30.5 ppm, and 60 mg/m^3 or nearly 52 ppm [22] for an average exposure of half an hour [23]. The study finds that CO concentration exceeds the WHO standard while cooking with biomass fuels. WHO [24] reported that breathing higher levels of carbon monoxide causes symptoms such as headaches, dizziness and weakness in healthy people. Once inhaled, CO binds to haemoglobin with an affinity 250-300 times than of oxygen [25], thereby forming carboxyhemoglobin (COHb).

This results in a decrease in the amount of oxygen in blood, thus causing tissue hypoxia [26, 27]. A study by Patel and Riyani [28] reported indoor air CO levels of 136.2 ppm, 94.3ppm and 12.2 ppm during cooking by wood, kerosene and LPG respectively. Similarly, Smith [29] has estimated that about 5 and 2g/meal CO is released during the household cooking, using wood and kerosene respectively. The results also show that maximum CO_2 emission was observed for biomass (2010 ppm) followed by kerosene (887 ppm) and LPG (512 ppm) fuels.

The mean concentrations of SPM samples were found to be 17, 1494 and 4804 $\mu g/m^3$ for, LPG, kerosene and biomass respectively. The maximum SPM concentration recorded during cooking with biomass fuel is higher than the WHO Air Quality Guidelines (50 µg/m^3 for 24 hr).The investigations revealed that there was significant variation in concentration of SPM level and was found to be highest for biomass (10,063 µg/m^3) and lowest for LPG (22 µg/m^3) fuel. The studies carried out in rural households of India, pollutants emissions from the use of one kilogram of wood/hour in fifteen approximate footage of forty meter cubed kitchens emits, among others pollutants, carbon monoxide and particulate emission of 150 and 3.3 mg/m^3 respectively compared to the allowable standard of 10 and 0.1 mg/m^3 respectively [30]. Therefore, this investigation clearly indicates that LPG fuel is the least contributor for CO, CO_2 and SPM than biomass and kerosene fuel. Similar observations were recorded by Balakrishna et al., [31]. They have reported that the kerosene, coal or biomass have produced higher levels of gaseous pollutant than LPG gas or electricity in homes.

Table 1: Concentration of indoor air pollutants generated during cooking with different fuels in the rural households

Energy sources	Pollutants								
	CO (PPM)			CO_2 (PPM)			SPM (µg/m^3)		
	Average	Maximum	Std. Dev*	Average	Maximum	Std. Dev*	Average	Maximum	Std. Dev*
Biomass	20	60	16	877	2010	428	4804	10063	2673
Kerosene	16	24	7.1	732.5	887	205	1494	2260	663
LPG	2	03	0.7	478.4	512	28	17	22	7.3

Table 2: Indoor air pollutants generated during usage different biomass cook stoves for cooking

Biomass cook stoves	Pollutants								
	CO (ppm)			CO_2 (ppm)			SPM (µg/m^3)		
	Average	Maximum	Std. Dev*	Average	Maximum	Std. Dev*	Average	Maximum	Std. Dev*
Traditional	46.67	60	12.6	1803	2010	205	9352	10063	1005
Clay	23	35	11.9	925	1409	368	3289	3704	671
Astra	10.25	29	6.5	650	968	118	2780	3571	691
Metal	33.3	40	7.6	781	878	105	6322	6897	813

*Standard deviation

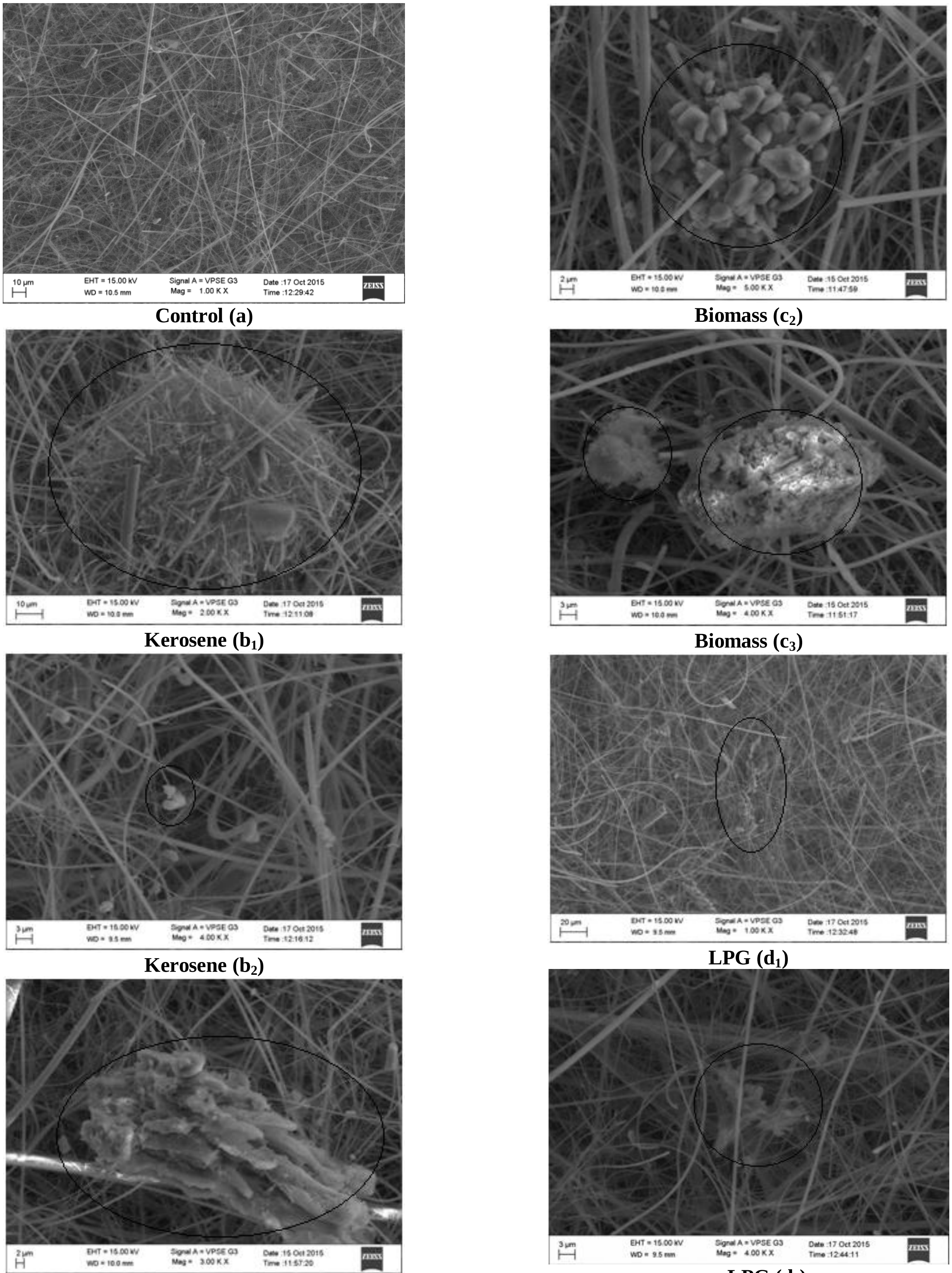

Figure 1: SEM images of SPM for different cooking fuels; control (a- clear micro glass fiber filter paper), kerosene (b_1-b_3), biomass (c_1-c_2) and LPG (d_1-d_2)

SEM was used to characterize the surface morphology of suspended particulate matter samples. The SPM samples were collected on filter paper during cooking with different fuels; biomass, kerosene and LPG. The SEM images of SPM for different fuels are shown in Figure 1. As shown in SEM images, the suspended particulate matters were cluster, irregular and spherical in shape. The morphology of carbonaceous particle varies depending on the fuels, burning conditions and atmospheric process [36, 37, 38]. In control, clearly indicates the absence of SPM while in kerosene cylindrical, spherical and cluster shaped SPM were found. In biomass SEM images, spherical, reticular, angular and irregular shaped structures were found. There is also strong evidence that fine particles play an important role in the observed health effects [39]. Particle behavior in the lung is dependent upon the aerodynamic characteristics of particles in flow steams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regimes of the respiratory system depends on their sizes [40]. The evaluation of SEM images also revealed that load of SPM were found to be very less in LPG (branched and irregular shape) as compared to biomass and kerosene fuels. The results showed that 80 - 90 % of the particles are smaller than 10 µm. Study also revealed that size of suspended particulate matter has varied among different fuels. A clear distinction is that particles smaller than 2.5 µm penetrate into the alveoli and terminal bronchioles; larger particles of up to 10 µm will deposit primarily in the primary bronchi, and much larger particles (up to 100 µm) will deposit in the nasopharynx. These size fractions arise primarily from combustion emissions and secondly from particles produced by gas-to-particle conversion processes. They are inherently unstable and grow into larger particles through coagulation and condensation [41]. The smoke deposits surfaces may contain dust, sulfate, nitrate and also oxides of different metals dominating by carbonaceous species [42].

Conclusion

The present study revealed that rural household of Chamarajanagar taluk have been exposed to higher concentration of CO, CO_2 and SPM during cooking with use of biomass fuels. It was observed that a very high concentration of CO (60 ppm) was released from biomass fuels has resulted in rising the carboxyhaemoglobin content in blood of human beings. The SPM generated from biomass and kerosene fuel have exceeded the permissible limits specified by WHO. A significant decrease in the concentration of CO and CO_2 was observed with the usage of Astra cook stove. The study also presents that morphological characterization of suspended particulate matter has varied in shapes and sizes. The morphology, size and the load of the particles emitted from different fuels have been confirmed by SEM studies. The study strongly suggests the use of improved cook stove, cleaner fuels and maintenance of good ventilation in cooking is helpful in reducing the indoor air pollutants and thus may benefit for better health of the households.

Acknowledgement

Author Komala H.P., is thankful to Department of Science and Technology (DST), New Delhi for awarding Inspire fellowship. Author A. G. Devi Prasad is thankful to University Grants Commission (UGC), New Delhi for financial assistance to major research project. Also authors thank to the Institute of Excellence (IOE), University of Mysore, Mysore for providing laboratory facility.

References

1.Akunne A.F., Louis V.R., Sanon M. and Sauerborn R., Biomass solid fuel and acute respiratory infections: The ventilation factor, Int. J. Hyg. *Environ. Health*, **209**: 445-450 (**2006**)

2.Arbex M.A., Martins L.C., De Oliveire R.C., Pereira L.A.M., Arbex F.F. and Cancado J.E.D., et al., Air pollution form biomass burning and asthma hospital admission in sugarcane plantation area in Brazil. *J. Epidemiol.Commun. Health*, **61**: 395-400 (**2007**)

3.Huboyo H.S., Tohno S., and Lestari P., et al., Characteristics of indoor air pollution in rural mountainous and rural coastal communities in Indonesia, *Atmos. Environ*, **82**: 343-350 (**2014**)

4.Smith K.R: Indoor air pollution implicated in alarming health problems. In: Indoor air pollution energy and health for poor, News Letter, 1 (**2003**)

5.Mondal N.K., Saha S.K., Datta J.K. and Banerjee A, Indoor air pollution: A household study in the village Faridpur and Ranchi Colony, Durgapur, Burdwan District, West Bengal, *World J. Environ. Poll*, **1**: 5-7 (**2011**)

6.Ezzati M., Mbinda B.M. and Kammen D.M., Comparison of emissions and residential exposure from traditional and improved biofuel stoves in rural Kenya, *Envrion. Sci. Technol*, **34**:578-583 (**2000**)

7.Smith K.R., Samet J.M., Romieu I. and Bruce N, Indoor air pollution in developing countries and acute lower respiratory infections in children, *Thorax*, **55**: 518-532 (**2000**)

8.Salam A, Mahmodul Hasan, Bilkis A., Begum, Monira Begum, Swapan K. and Biswas, Chemical characterization of biomass burning deposits from cooking stoves in Bangladesh, *Biomass and Bioenergy*, **52**: 122-130 (**2013**)

9.WHO, Fuel for life: Household Energy and Health (**2006**)

10.Tian L., Zhang G., Zhang Q., Moschandreas D.L., Hao J., Lin J., and Lin Y, The impact of kitchen activities on indoor pollution concentrations, *Indoor Built. Environ*, **17**: 377-383 (**2008**)

11.Lim S, Vos T, Flaxman AD, Danaei G, Shibuya K, and Adair Rohani H, et al., A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factors clusters in 21 regions 1990-2010: a systematic analysis for the global burden of disease study 2010. Lancer; 380:2224-60 (**2012**)

12.Bhargava A., Khanna, R.N., Bhargava S.K. and Kumar, S: Exposure Risk to Carcinogenic PAHs in IndoorAir during Biomass Combustion Whilst Cooking in Rural India. *Atmos. Environ*, **38**: 4761–4767 (**2004**)

13.Pokhrel A.K., Smith K.R., Khalakdina A., Deuja A. and Bates M.N., Case-Control Study of Indoor Cooking Smoke Exposure and Cataract in Nepal and India, *Int. J. Epidemiol*, **34**: 702–708 (**2005**)

14.Kanishtha T., Banerjee R., and Venkataraman C., Effect of Particle Emissions from Biofuel Combustion on Surface Activity of Model and Therapeutic Pulmonary Surfactants, *Environ. Toxicol. Pharmacol*, **22**: 325–333 (**2006**)

15.Padhi B.K., and Padhy P.K., Domestic Fuels, Indoor Air Pollution, and Children's Health: The Case of Rural India, *Ann. N.Y. Acad. Sci*, **1140**: 209–217 (**2008**)

16.Mondal N.K., Mukherjee B., Das D., and Ray M. R., Micronucleus Formation, DNA Damage and Repair in Premenopausal Women Chronically Exposed to High Level of Indoor Air Pollution From Biomass Fuel Use in Rural India, *Mutat. Res.Genetic Toxicol. Environ. Mutagen*, **697**: 47–54 (**2010**)

17.He G, Ying B, Liu J, Gao S, Shen S, and Balakrishnan K, et al., Patterns of household concentrations of multiple indoor air pollutants in China, *Environ Sci Tech*, **39 (4)** : 991-8 (**2005**)

18.Jackson M.M., Cooking as a source of indoor air pollution in rural areas of Tanzania, *Int.J.Bio.Chem.Sci*, **3(5)** : 934-947 (**2009**)

19.Joon V, Krishna Kumar M., Bhattacharaya and Avinash Chandra, Non-Invasive Measurement of carbon monoxide in rural Indian woman exposed to different cooking fuel smoke, *Aerosol and Air Quality Research*, **14**: 1789-1797 (**2014**)

20.Singh P, Renuka Saini, and Ajay Taneja, Physicochemical characteristics of PM 2.5: Low, middle and high-income group homes in Agra, India-a case study, *Atmospheric Pollution Research*, **5**: 352-363 (**2014**)

21.Shilpa B.S. and Lokesh K.S, Morphology of respirable suspended particulate matter (RSPM) emitted from household fuels and their health implications, *International journal of engineering sciences and research technology*, **3(6)**: 204-208 (**2014**)

22.Canadian Centre for Occupational Health and Safety (CCOHS), Converting Occupational Exposure Limits from mg/m^3 to ppm, http://www.ccohs.ca/oshanswers/chemicals/ convert.html (Accessed on 1.01.2014) (**2014**)

23.WHO, WHO Guidelines for Indoor Air Quality: Selected Pollutants, World Health Organization, Geneva (**2010**)

24.WHO, Air quality and health: fact sheet, 313 (**2008**)

25.Raub J.A., Mathieu Nolf M., Hampson N. B and Thom S. R, Carbon monoxide poisoning - a public health perspective, *Toxicology*, **145(1)**: 1–14 (**2000**)

26.Roughton F.W. and Darling R.C, Effect of Carbon Monoxide on the Oxyhemoglobin Dissociation Curve, *Am. J. Physiol*, **141**: 17–31 (**1944**)

27.Piantadosi, C.A., Toxicity of Carbon Monoxide: Hemoglobin vs. Histotoxic Mechanisms, In Carbon Monoxide, Penney, D.G. (Ed.), CRC Press, Boca Raton, FL, 163–180 (**1996**)

28.Patel T.S. and Riyani C.V., Indoor Air Quality: Problems and perspectives, In Energy Strategies and Green House Gas Mitigatio, Shukla, P.R. (Ed.), Allied Publishers, New Delhi, 72 (**1995**)

29.Smith K.R., Managing the Risk Transmission, *Toxicol. Ind. Health*, **7**: 319 (**1991**)

30.UNEP, Report on Development and harmonization of environmental standards in East Africa. UNEP, Nairobi Kenya, **2**: 22-28 (**1999**)

31.Balakrishnan K. and Ramaswamy P., et al., Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Global Health Action (**2011**)

32.Ravindranath N.H., Energy options for cooking in India. Energy Policy, **25(1)** : 63-75 (**1997**)

33.Singh S, Gyan Prakash Gupta, Bablu Kumar and Kulshrestha U.C: Comparative study of indoor air pollution using traditional and improved cooking stoves in rural households of Northern India, *Energy for sustainable development*, **19**: 1-6 (**2014**)

34.Goncalves C, Alves C, Evtyugina M, Mirante F, Pio C, and Caseiro A, et al., Characterization of PM 10 emissions from wood stove combustion of common woods grown in Portugal, *Atmos. Environ*, **44**: 4474-80 (**2010**)

35.Prapas J., Baumgardner M.E., Marchese A.J., Willson B. and Defoort M, Influence of chimneys on combustion characteristics of buoyantly driven biomass stoves, *Energy for sustainable development,* **23** : 286-293 (**2014**)

36.Berube K.A., Jones T.P., Williamson B.J., Winters C., Morgan A.J. and Richards R.J., Physicochemical characterization of diesel exhaust particles: Factors for assessing biological activity, *Atmospheric Environment,* **33**: 1599-1614 (**1999**)

37.Posfai M and Buseck P. R., Nature and climatic effects of individual trophospheric aerosol particles, *Annual Review of Earth and Planetary Sciences,* **38**: 17-43 (**2010**)

38.Tumolva L., Park J.Y., Kim J.S., Miller A.L., Chow J.C, Watson J.G. and Park K., Morphological and elemental classification of freshly emitted soot particles and atmospheric ultrafine particles using the Tem/EDS, *Aerosol Science and Technology,* **44**: 202-215 (**2010**)

39.Stern A.C., Boubel, R.W. and Turner D.B., Fundamental of Air Pollution, 2nd Edition, Academic Press, Inc (**1984**)

40.Akeredolu F.A., Environmental Engineering Notebook, Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria (**1996**)

41.Kelly F.J and Fussell J.C., Size source and chemical composition as determinants of toxicity attributable to ambient particulate matter, *Atmos. Environ,* **60**: 504-526 (**2012**)

42.Salma I., Dpsztaly K., Borsos T., Soveges B., Weidinger T., Kristof G., Peter N. and Kertesz Z, Physical properties, chemical composition, sources, spatial distribution and sinks of indoor aerosol particles in a university lecture hall, *Atmospheric Environment*, **64**: 219-228 (**2013**).

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Advances in Applied Science Research, 2016, 7(1):85-89

ISSN: 0976-8610
CODEN (USA): AASRFC

Biomass: A key source of energy in rural households of Chamarajanagar district

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ABSTRACT

Biomass is the most prominent renewable energy resources. It plays a vital role in meeting the domestic energy needs among the rural households of developing countries. The present study has been made to assess the utilization pattern of fuel sources among the households of five selected villages of Chamarajanagar district. The calorific values of commonly used firewood species have been determined. The results have shown that there is a greater dependency on biomass energy for domestic needs as compared to commercial ones. Firewood is the primary energy source (98.62%) for cooking and heating purposes among the rural households. The investigation has revealed that about half of the households are using different fuel wood species without the awareness of thermal efficiency in their traditional biomass cook stoves. An attempt has been made to investigate the calorific values of the fuel wood species used by them. Based on the findings it has been suggested usage of species with greater heating efficiency with lesser quantity would be sufficient to meet their daily energy requirements

Keywords: Biomass, Cook stove, Chimney, Ventilation, Calorific value.

INTRODUCTION

Energy is the basic unit which plays an important role in socio-economic development of any region. It is widely recognized that energy is linked in numerous ways to the achievement of virtually all Millennium Development Goals (MDGs), in terms of reducing poverty, improving human welfare and raising living standards [1]. Demand of energy requirement is directly proportional to the development rate and population growth rate of the country. The availability of energy source is in the form of renewable and non-renewable energy sources. Among these, biomass is a kind of most promising and alternative renewable energy resources. It includes firewood, agricultural residues, dung and animal waste. This is the main source of energy for rural households for cooking and heating purposes. Biomass demand continued to grow steadily in the heat, power, and transport sectors. Total primary energy consumption of biomass reached approximately 57 exajoules (EJ) in 2013 of which almost 60% was traditional biomass, and the remainder was modern bioenergy (solid, gaseous, and liquid fuels) [2].

India derives the bulk of its cooking energy needs from solid fuels, such as firewood, crop residues or cattle dung [3]. The utilization of biomass as energy source in India is more because, about 70% of people are living in rural areas. Moreover, traditional energy sources such as biomass account for over 26% of India's total primary energy consumption. That is more than India's consumption of oil, which stands at 24%. Fuel wood is the universal source of energy, accounting for 60% of the total fuel requirement in rural India [4]. Rao and Reddy [5] reported that socio-economic factors have strong influence on choice of households energy sources in India.

Women and children are mainly involved in collection and combustion of firewood and are thus highly exposed to biomass smoke. Biomass smoke contains many noxious components, including respirable suspended particulates, carbon monoxide, nitrogen oxides, formaldehyde, and polyaromatic hydrocarbons, such as benzo[α]pyrene. High exposures to these pollutants in indoor environment can cause serious health problems [6, 7, 8]. The levels of these pollutants mainly depend on the cook stoves, fuels and housing pattern (ventilation). Cooking areas in many households are poorly ventilated, and about one-half of all households do not have a separate kitchen [9].

Cook stoves used by the rural households are very simple and are not properly designed to remove biomass smoke particles during combustion process. This has lead to reduction in the thermal efficiency as well as their high exposure to high levels of indoor air pollutants. In developing countries, such as India, daily air pollution exposures from cooking with biomass typically exceed relevant health based guidelines by factors of 20 or more [10]. In view of this the present investigation was carried out to assess the utilization pattern of biomass energy resources in five villages of Chamarajanagar district.

MATERIALS AND METHODS

The study was carried out in five villages namely Chandakavadi, Kethanahalli, Sampigepura, Baragi and Kadabur of Chamarajanagar district, Karnataka. It is located at $11^0\,40'$ to $12^0\,48'$ North latitude and $74^0\,52'$ to $76^0\,07'$ East longitude. This district has geographical area of 5676 Sq. Kms comprising a population of about 10,20,962. Random sampling of households was made for collecting the data and information on several household parameters by personal interviews. The survey was conducted to identify and quantify the fuel sources and their utilization pattern in the households. A questionnaire was designed to collect the data pertinent to socio-economic conditions, fuel sources, housing characteristics and type of cook stoves used by the households.

Determination of Calorific value:
The commonly used firewood species by the households were collected and processed for determination of its calorific values. One gram of the wood powder was oven dried to constant weight and burned in an oxygen bomb calorimeter (Model AC 350) for finding the calorific value.

RESULTS AND DISCUSSION

Socio-economic characteristics of households surveyed in five villages are shown in Table 1. Among the respondents 62 % are females and 38% are males; while 66 % are illiterates and 34% are literates. From this it is evident that the literacy rate is low in these villages. Based on the landholdings of the respondents the households are categorized as landless or low (below 1 acre), middle (1-5 acre) and high (above 10 acre). Among these, 24% of households posses land below 1 acre, 34 % have 1-5 acres, 1% with more than 10 acres and 41% of households are landless. The households are classified into four types based their economic status as; low (Rs.1,000-Rs.10,000), middle (Rs.11,000-Rs.50,000), high (>Rs.50,000) and without income. Among these villages most of the households (42.3%) come under the category of low income level while 26% of the households have no fixed income. Households with low, middle and without income groups are mainly dependent on biomass energy sources.

Table 1: Socio-economic characteristics of rural households

Name of the villages	Socio-economic characteristics											
	Gender		Literacy (%)		Land holdings (%)				Income (%)			
	Male	Female	Literate	Illiterate	Nil	Low	Medium	High	Nil	Low	Medium	High
Chandakavadi	263	522	43.3	56.7	48	37.3	13.7	1	51	28	20	1
Kethanahalli	100	44	31.7	68.3	24.75	25.75	47.5	2	10.9	33.7	51.5	3.9
Sampigepura	32	51	39.4	60.6	8.45	28.17	61.97	1.41	11.3	57.7	22.5	8.5
Bargai	191	374	50.4	49.6	27	26.6	46	0.4	9.3	63.7	23.8	3.2
Kadabur	38	24	4.8	95.2	97.6	2.4	0	0	47.6	28.4	24	0

***Landholdings** - low < 1acre, middle – 1-5 acre, high > more than 10 acre. **Income**- - low (Rs.1,000-10,000), middle (Rs. 10,000-50,000), high >Rs. 50,000. **Nil**- Landless /without income.*

Table 2 presents the type of energy sources used as fuel for domestic purposes. The results have shown that firewood is the primary and dominant energy source for their daily requirement. The households use four types of energy sources such as firewood, agricultural residues, kerosene and liquid petroleum gas (LPG) for cooking and heating purposes. Among the villages investigated, 100% of firewood utilization was recorded at Kethanahalli, Sampigepura and Kadabur. The study revealed that there were no LPG users in Kadabur as it is noticed that 47.6% of households have no income. This clearly indicates that there is a strong correlation between the choice of fuel source and income status. The usage of commercial energy sources such as kerosene and LPG found to be 15.2% and 34.4% respectively. It was evident from the studies that biomass was the major energy source for households as compared to conventional energy sources.

Table 2: Type of energy sources used as fuel for domestic purposes by the households (%)

Name of the villages	Energy sources			
	LPG	Kerosene	Firewood	Agricultural residues
Chandakavadi	29.6	37	94.7	51.8
Kethanahalli	15.8	5	100	82.2
Sampigepura	43.7	11.3	100	88.7
Bargai	82.7	20.2	98.4	72.6
Kadabur	0	2.4	100	21.4
Mean	34.4	15.2	98.6	63.3

The trees commonly used as firewood by the people and their calorific values are shown in Table 3. A total of 15 species belonging to 9 families were identified which are commonly used as fuel wood. Calorific value is an important parameter to assess the combustibility of any flammable material. The results have shown that, calorific value of firewood species ranged between 2847 to 7189 cal/gm. *Casuarina equisetifolia* has shown highest (7189 cal/gm) calorific value while *Syzygium cumini* showed lowest calorific value. The wood of most species of *Casuarina* is heavy, dense and very hard. The casuarinas produce high quality of fuel wood and charcoal, the wood is easily split and has low ash content. It makes an excellent fuel wood, producing good heat while being relatively smokeless and has been called 'the best firewood in the world'. It burns readily even when green and makes exceptionally fine charcoal [11]. The density of wood is 900-1000 kg/m^3.

The quantity and time involved in collection of firewood and its consumption per household are shown in Table 4. The people used to travel a distance of 1.5 km to 2 kms for collection of firewood. The time spent to collect fuel wood on an average of 29 kg per day was around 2 hrs. It is recorded that on an average 4.2 kg of firewood is consumed per household per day. The consumption level of firewood is all most similar in Chandakavadi, Kethanahalli, Baragi and Kadabur except in Sampigepura. The quantity of firewood utilization by the households mainly depends on type of fuel wood, household size and seasonal conditions.

Table 3: Calorific value of commonly used firewood species

SL. No	Scientific name	Family name	Local Name	Calories/gm
1	*Cocos nucifera*	Arecaceae	Tengu	4898
2	*Ficus benghalensis*	Moraceae	Aala	5784
3	*Tamarindus indica*	Leguminaceae	Hunase	6071
4	*Morinda tinctoria*	Rubiaceae	Maddi	3907
5	*Casuarina equisetifolia*	Casuarinaceae	Suragi	7189
6	*Syzygium cumini*	Myrtaceae	Nerale	2847
7	*Ficus glomerata*	Moraceae	Atti	4781
8	*Artocarpus heterophyllus*	Moraceae	Halasu	5111
9	*Pongamia pinnata*	Leguminosae	Honge mara	4350
10	*Acacia nilotica*	Leguminosae	Gobbali	3800
11	*Thespesia populnea*	Malvaceae	Buguri	3121
12	*Eucalyptus globulus*	Myrtaceae	Neelagiri	3811
13	*Tectona grandis*	Lamiaceae	Thega	4850
14	*Cassia fistula*	Leguminosae	Kakke	4897
15	*Azadirachta indica*	Meliaceae	Bevu	5116

Table 4: Quantity and time involved in collection of firewood by the villagers

Name of the villages	Distance travelled (km)	Time spent / collection (hr)	Firewood collection/day (kg)	Firewood consumption/ Household/day (in kg)
Chandakavadi	2	1	30	4.3
Kethanahalli	2	2	27	4
Sampigepura	1.6	1.8	26	3.82
Bargai	1.7	2	29.9	4.6
Kadabur	1.5	2.5	32.5	4.5
Mean	1.8	1.9	29	4.2

Table 5: Type of biomass cook stoves used by the households

Name of the villages	Type of cook stoves used by households (In Percentage)			
	Traditional	Clay	Metal	Astra
Chandakavadi	3.52	44.4	3.2	41
Kethanahalli	17.8	29.7	14.85	37.6
Sampigepura	3	15.5	1.22	80.28
Bargai	3	22.6	3	68
Kadabur	33.3	45	21.7	0
Mean	12	31	8.8	45.4

The different types of biomass cook stoves used by the households in these villages are shown in Table 5. People use four types of cook stoves for biomass fuels such as traditional, clay, metal and Astra. Among these stoves Astra is considered as an improved cook stove because it is designed to capture maximum heat along with a chimney to remove suspended particulate matter generated during combustion. This type of cook stove is used by 45.4% of the households followed by clay (31%), traditional (12%) and metal (8.8%) stove. During the study it was recorded that no households used Astra stove in Kadabur village as they exclusively depend on clay stoves. This may be because of the cost of Astra stove which is costlier to clay stove. The traditional stove is made up of three stones which consume more firewood with much loss of heat as compared to other stoves.

Table 6: Housing pattern and location of cook stoves in the households

Name of villages	Housing pattern				Location of cook stove		
	Chimney without ventilation	Chimney with ventilation	No chimney and no ventilation	Ventilation without chimney	Outside of the house	Living area	Separate kitchen
Chandakavadi	6.34	41.55	18	34.11	13.7	24.3	62
Kethanahalli	16.8	52.5	1	29.7	2	8	90
Sampigepura	0	85.9	0	14.1	1.4	4.2	94.4
Baragi	3.6	87.2	6	3.2	4.4	12.5	83.1
Kadabur	7.14	28.6	4.76	59.5	2	90.86	7.14
Mean	7	59	6	28	5	28	67

The cooking area and housing pattern were found to be different among the households (Table 6). Most of the households cook at separate kitchen while others cook in living room and outside the house. It was observed that 67% of households used to cook exclusively in separate kitchen. The results have shown that only 59% of houses are having good ventilation and chimney. The ventilation and chimney are most important characteristics which help in reduction of indoor air pollutants. Opened door and window in a kitchen lowered the particulate matter (PM) 1-hour concentration between 93 to 98% as compared to closed kitchen [12].

CONCLUSION

The results of the investigation have revealed that there is a greater dependency on biomass energy sources in the rural households of Chamarajanagar. Commonly available firewood species are being randomly used as fuel wood by the households without knowing the thermal efficiency. A poorly designed biomass cook stove is mainly used for cooking and heating processes. This is because of socio-economic constraints involving affordability to purchase improved cook stoves, lack of awareness/willingness to shift from the traditional practice to recent technologies for cleaner fuels. The determination of calorific values of fuel wood species can aid in identification of suitable species for better utilization of biomass energy. Recommendation of growing such species in wastelands of their vicinity helps in promoting self-sustenance so as to provide better security in supply of energy sources.

Acknowledgement
Author Komala H. P., is thankful to Department of Science and Technology (DST), New Delhi for awarding Inspire fellowship. Author A. G. Devi Prasad is thankful to University Grants Commission (UGC), New Delhi for financial assistance to major research project.

REFERENCES

[1] Barnes D.F. (Ed.), Resources for the Future Press, **2007**.
[2] Renewable energy policy network for the 21st century (Global Status Report-**2014**), REN 21, secretariat, Paris, France, **2014**.
[3] Sehgal M., A. Garg, P. Mohan and H. Hombergh, Cooking fuels in India: Trends and patterns. The Energy and Resources Institute, New Delhi. Policy brief, 3, **2010**.
[4] Pandey D., Fuel wood studies in India-Myth and Reality. Centre for International Forestry Research (CIFOR), Indonesia 94, **2002**.
[5] Narasimha Rao M. and B.S. Reddy, *Energy*, **2007,** 32 (2):143-153.
[6] WHO (World Health Organization). Epidemiological, social, and technical aspects of indoor air pollution from biomass fuel: report of a WHO consultation, June **1991**. Geneva: World Health Organization, **1992**.
[7] Smith K.R., Biofuels, air pollution, and health: a global review. NewYork: Plenum Press, **1987**.
[8] Smith K.R, *Ann Rev Energy and Env*, **1993**, 18:529-566.
[9] IIPS (International Institute for Population Sciences). National family health survey (MCH and Family Planning): India **1992**-93. Bombay: International Institute for Population Sciences, **1995**.
[10] Smith K.R. and Liu Y. *Lung Biology in Health and Disease Series*, **1994**; 74: 151-184.
[11] Michael D. Benge, Casuarinas "the best firewood in the world", Resources for charcoal, construction poles, windbreaks and shelterbelts and soil erosion and sand dune stabilization. Technical, series, Agency for International Development Washington, **1982**.
[12] Kelley Grabow, Dean Still and Sam Bentson. *Energy for sustainable development*, **2013**, 17: 458-462.