CHAPTER 4

DISCUSSION

Energy is an integral part of a society and plays an important role in socio-economic development. The state of economic development can be assessed from the consumption of quality of energy. Throughout the various stages of development, human beings has experimented with various sources of energy e.g. wood, coal, oil, petroleum, solar energy and nuclear power etc. A whopping 70% of the country’s population still lives in rural areas which are primarily engaged in agriculture. There is tremendous demand on resources such as fuel wood, agricultural residues, etc. to meet the daily fuel requirements. In many developing countries biomass is the major source of energy nearly accounting for 30% of the country’s energy use reaching levels as high as 75-90% (Ramachandra and Kamakshi, 2005). This component is much higher in rural areas (Reddy and Venkataraman, 2002).

In many of the poorest countries, 80% or more of all national fuel combustion occurs under cooking pots. India is the second largest consumer of biomass fuels in Asia. Indian households still continue to consume around 40% of the energy by this traditional biomass fuels (TBF). TBF typically burnt in simple stoves with incomplete combustion leads to indoor air pollution. Because of poor combustion conditions significant part of the fuel carbon converts into products of incomplete combustion (Smith et al. 2000b). Women and children are
exposed to high levels of such indoor air pollution every day (Bruce et al., 2000) and suffer from various types of health impairments and increase the disease burden of the country. Epidemiological studies have revealed that domestic biomass fuel smoke exposure has a risk factor for the development of respiratory diseases (acute bronchitis, chronic pulmonary diseases etc.), and non respiratory diseases (ocular diseases, cardiac diseases, reproductive problems etc.) and adverse pregnancy output.

The health effects on the exposed subjects depend upon the type of fuel used, ventilation of kitchen, types of stoves, time spend during cooking, number of meal prepared, area of cooking place etc. The housing conditions of the people are important causative factors of nature and level of risk. Present study is a good example of environmental exposure to BMF smoke on health on women. The study subjects exposed to BMF smoke do not follow any preventive measures during domestic cooking (Fig. 4.1). Periodic and long time exposure to BMF smoke leads to detrimental health effects. This is a unique study in terms of BMF smoke among Indian rural women. BMF smoke related morbidity of various organ systems (e.g. respiratory, ocular, musculoskeletal, dermal, genitourinary), allergic problems, impairment in variables of menstrual cycle, early menopause, change in menarche age, adverse pregnancy outcomes, neonatal and infant mortality, etc. are the significant findings in the present study.

Although there are many studies having been conducted earlier by many authors regarding health hazards attributed to biomass fuel smoke in developing countries, the studies on health problems among the rural females exposed to BMF smoke in India are not many in number.
Physical Characteristics like age, height, weight and Body Mass Index (BMI) of exposed and control subjects were found to be approximately similar. Women and adolescent girls have experience of domestic cooking from 0.5 to 50 years. Cooking is done usually inside the house. The time spend for cooking per day is about 0.5 to 4 hours per day.

Clinical examination showed significant problems for respiratory system, ocular system, genitourinary system, and change in menarche age, variability in
menstrual cycle, dermal problems, dental and allergic problems among exposed women as well as infant and neonatal mortality as compared to control subjects which clearly depict the adverse health effects of BMF smoke among exposed subjects. The symptoms for illness in different organ systems observed among the exposed women are mainly chronic. Significant symptoms for allergic problems (p<0.05), respiratory system (p<0.05), dermal (p<0.05), dental (p<0.05), exhibit the effect of BMF smoke among exposed women. Similarly other studies regarding exposure to BMF smoke show some agreement with the findings of health risks among women in the present study. In a study conducted in South India, the signs and symptoms of illnesses due to exposure of BMF smoke reported were reduction of lung function, acute respiratory problems etc. (Padmavati and Joshi, 1964) which are also found in the present study. In a similar kind of north Indian study among women exposed to biomass fuels; respiratory, gastrointestinal, ocular and dermal problems were observed (Bihari et al., 2008; ITRC, 2005). However the studies did not report the problems related to various variables (components) of menstrual cycle, as in the present study.

In an earlier study, women exposed to biomass fuel in developing countries were found to show symptoms of chronic respiratory health problems by Malik (1985), Master (1974), Pandey (1984a,b). Tuberculosis was also reported by Mishra et al (1999a,b). Gupta et al. (1997) also reported similar findings from North India (near Lucknow). Impairment in lung function was also reported by Malik and Behara (1989), and Davidson et al. (1981). Adverse pregnancy outcomes were reported by Mavlankar et al. (1991) and Lakshmi et al. (2013). Lung Cancer was also reported by Behara and Balamugesh (2005) and
Hernandez-Garduno et al. (2004). All the problems except the lung cancer are also found in the present study. Other studies show that the association of pollution concentration (NO₂, SO₂, CO) with intrauterine mortality and adverse effects on fetus (Pereira et al, 1998). Mishra et al. (2005) indicated that women who cook with wood, cow dung, or crop residue are significantly more likely to have experienced a still birth than those who cook with LPG, biogas, or electricity. The birth defects (congenital anomaly) were also reported by Ritz et al, (2002). Infant mortality and neonatal mortality due to air pollution were also reported by Bobak and Leon. (1999); Woodruff et al. (2006), Lipfert et al. (2000), Chay and Greenstone, (2003), Lin et al. (2007). All the above findings are also found in the present study.

Alteration in reproductive capacity, infertility, endometriosis etc. were reported by Mc Lachen, (1993), Colborn (1995), Jenson et al. (1995), Safe (1995), Vom Saal (1995). They mentioned that the chemical and pollutants with steroid like activities could disrupt normal endocrine function. Pollution caused by biomass fuel smoke also contains such types of chemicals, which act as endocrine disrupters and change the hormonal imbalance and cause impairments in variables of menstrual cycle. Such types of finding support the findings in the present study.

In the present study, it has been observed that women using biomass fuel for domestic cooking suffer from increased prevalence of respiratory symptoms which was significant (p<0.05) as compared to controls. The indoor air pollution due to inefficient combustion of biomass fuels has been linked with the prevalence of upper and lower respiratory illness. It includes breathlessness, recurrent cough & cold, productive cough, pulmonary tuberculosis etc. In our
study the prevalence of breathlessness, recurrent cough & cold, productive cough (upper respiratory problems), pulmonary tuberculosis (lower respiratory problems) were observed among biomass users as compared to controls. The higher prevalence of upper and lower tract problems has been reported by Honicky et al. (1985). Diaz et al. (2006) presented a case report “hut lung” (noninfectious, nonmalignant respiratory manifestations of chronic, high-level exposures to biomass smoke). Smoke from solid fuels contains hundreds of chemicals (Smith and Liu, 1994). Many of them are toxic to the bronchial mucosa and alveoli. These chemicals have ability to form free radicals (Haponic, 1993). When these chemicals are inhaled in sufficient concentrations, they tend to produce acute neutrophilic airway-inflammation which results into cough, dyspnea and wheezing (Laffon et al., 1999). Exposure to smoke interferes with the mucociliary defences of the lungs (Houtmeyers et al., 1999) and reduces many antibacterial properties of lung macrophages, such as phagocytic rate (Fick et al., 1984, Beck and Brain, 1982). Fine and ultra fine particles are also present in the smoke which is formed during combustion process. According to Ellegard (1996), the biomass emits more particles than LPG or electricity during cooking (Ellegard, 1996). Lal et al. (1993) in animal study showed histomorphological changes in lung of rats following exposure to wood smoke. Dung use, absence of separate kitchen and low socio economic status (SES) are also risk factors which contribute to the increase of the prevalence of respiratory problems. Inhalation of compounds including particulate matter (PM) enhance the symptom of underlying lung disease (e.g. asthma) etc. Study shows that these effects are mediated by mechanisms like lung inflammation, oxygen
deprivation. The cellular model study reveals that inflammatory responses that may be important in the adverse effect due to increase in exposure to particulate matter (Ghio and Huang, 2004.) According to Moshammer et al, (2006), in vitro research is directed towards dissecting cellular and molecular pathway. Among the cells that respond to particles are macrophages. The epithelial barrier cells that line the air spaces of lung also encounter the particles and are important in inflammation and defence (Donaldson et al., 2002). The inflammatory response also plays an important role in the adverse effects of PM (Moshammer et al., 2006).

The prevalence of tuberculosis was also observed by many authors. In 1992-1993 National Family Health Survey, Asikainen (2004) found a strong and statistically significant relationship between the use of biomass fuel and TB in India. Prevalence of tuberculosis was also reported by Mishra et al. (1999a, b). Mishra et al. (1999a,b) analysed the data of two lakh (200,000) Indians and concluded that persons living in households using biomass fuel had more chances of tuberculosis as compared to persons living in households using cleaner fuels. They also mentioned that about 59% of rural cases and 23% of urban cases of tuberculosis in India might be attributed to exposure to biomass fuel (Mishra et al., 1999a, b). A similar observation was also reported by Lakshmi et al. (2013), Kaplan (2010), Smith (2000), Perez-Padilla et al. (2001), Gupta et al. (1997), ICMR Bulletin (2001), Lin et al. (2007), Riaz and Sughis (2011), Pachauri et al. (2006).

The overall prevalence of genitourinary tract problems was not significantly associated with biomass fuel exposure in our study but the exposure index wise morbidity of genitourinary problems was highly significant. The prevalence of
genitourinary problems among subjects exposed to 21-50 hr-ys (31.11%) was found to be significantly higher (p<0.001) when compared to exposed subjects 0-20 hr-ys (3.17%) and >51 hr-ys (7.69%). Genito urinary problems were also reported by the Govt. of India (1988). The high rates of genitourinary and reproductive tract infections were observed among poor women. These problems might be due to lack of adequate water for bathing/washing etc in rural areas which is one of the contributing factors for such infections. Many of these women remain untreated for years leading to reproductive tract infection. Such findings are also reported by Bang and Bang (1989).

The overall prevalence of musculoskeletal problems (backache, body ache, pain in joints etc) was also observed in the study among women. Exposure index wise analysis shows the significant musculoskeletal morbidity. The prevalence of musculoskeletal problems among subjects exposed for more than 51 hr-ys (48.72%) was found significantly higher (p<0.001) when compared to exposed subjects 0-20 hr-ys (4.76%) and 21-50 hr-ys (31.11%). No significant changes in prevalence were observed between 0-20 hr-ys and 21-50 hr-ys., and for total morbidity. The various types of musculoskeletal problems among women were due to improper position during domestic cooking and gathering, carrying biomass fuel over long distances on their head (Fig 4.2) daily for many years, which leads to an extra burden on the body and causes various muscular problems such as muscular pains, backache etc. Similar findings are also reported by Batliwala and Reddy (2003), Yoshihito (2012) and Brulin et al. (1998) about musculoskeletal problems among home care women. Brulin et al. (1998) showed that combination of physical exposure and 'no possibility of
influencing the planning of work' gave an increase in odds ratio, indicating an interaction between these two exposure indices.

**Fig. 4.2-** Girl carrying biomass fuel (cow dung cake) on her head

Similarly Nourbakhsh et al. (2006) also indicated that certain muscle impairment could contribute to low back pain. Backache was also reported by Cholewicki et al. (1991). Diaz et al. (2007) also reported backache among Mayan Guatemalan women taking part in a randomized stove intervention trial. These findings of other authors also support our findings.
The overall prevalence of ocular problems (lacrimation, refractive error and sticky eyes) was also observed in this study among women. The prevalence of lacrimation and sticky eyes was higher among the exposed subjects as compared to the controls. The exposure index wise analysis shows that the ocular morbidity increases significantly with exposure index. The prevalence of ocular problems in subjects exposed for more than 51 hr-ys (46.15%) was found to be significantly higher (p<0.001) when compared to exposed subjects 0-20 hr-ys (6.35%) and 21-50 hr-ys (31.11%). Pollution attributable to biomass fuel causes eye irritation and may cause lacrimation, sticky eyes and refractive error. Irritation causing lacrimation attributed to biomass fuel was also described by Ellegard (1997). Mishra et al, (1999c) who suggested that exposure to biomass fuels smoke for cooking substantially increases the risk of partial blindness. Batliwala and Reddy (2003) also observed conjunctivitis, blepharo conjunctivitis and cataract in BMF exposed women. Diaz et al. (2007) also reported eye discomfort among Mayan Guatemalan women. The above studies conducted by other authors also support our findings. Exposure index wise it was observed that the prevalence of gastrointestinal morbidity among subjects exposed for more than 51 hr-ys (41.03%) was found significantly higher (p<0.001) when compared to exposed subjects 0-20 hr-ys (4.76%) and 21-50 hr-ys (20.00%). During processing the women may be exposed to unhygienic contents present in the excreta of cow/buffalo etc., which may lead to enteric infections. The health hazards might be due to preparing and processing of dung cake. Such findings were also reported by Batliwala and Reddy (2003).
A significant (p<0.05) prevalence of dermal problems was also observed among exposed as compared to controls. It indicates the adverse effect of biomass fuel smoke on skin among women engaged in domestic cooking. The dermal problems due to biomass cooking fuels are not only restricted to those arising from air pollution but also from each part of the fuel cycle (from production to processing to actual cooking). Dermal problems were also reported by Batliwala and Reddy (2003).

The overall prevalence of dental problems was significant (p<0.05) as compared to controls. It indicates the adverse effect of biomass fuel smoke on tooth among women engaged in domestic cooking. The burning of biomass fuel releases fluorine in the atmosphere. As a result, women are exposed to fluorine by inhalation. The fluorine thus reduced becomes fluoride. The fluoride also enters in the body of women mainly as a result of eating foods [e.g. Roti/Chapati (Indian bread)] dried over open fire pits (Wu and Li 1990; Yan, 1990). Continuous exposure to BMF for a long time leads to dental problems (teeth decay). A similar observation was reported by Zhang and Smith (2007).

The prevalence of allergic manifestation was significant as compared to controls. It indicates the allergic problems attributed to biomass fuel among women engaged in domestic cooking. The allergic manifestation may occur during gathering/ carrying fuel. Indoor air pollution contains allergens which may lead to allergic problems. In humid condition during flowering, the pollens come into the contact of soot and other dust particles. They tend to burst and allergens stick to the smaller particles’ surfaces. The chemical composition of air pollutants also stimulates the release of proinflammatory eicosanoid-like substances from pollen grains resulting in allergic problems. The pollution can
enhance allergic sensitization in subjects genetically at risk (Moshammer et al., 2006). Allergic reactions were also reported by Batliwala and Reddy (2003), Hoang et al. (2011), Smit et al. (2008), ISAAC Steering Committee (1998), and Behrendt et al. (2001). These studies also support our findings. The prevalence of headache was greater among biomass users as compared to LPG users. In this study the difference was not significant. The increased prevalence of headache may be due to higher levels of carbon monoxide (CO) in the breathing area due to biomass combustion. Headache is the commonest symptom of CO poisoning. The CO poisoning can occur in a person exposed to incomplete burning of fossil fuel e.g wood-burning stoves etc (http://www.codamage.com/). The similar findings were also reported by Diaz et al. (2007) which support our findings. In the present study it was observed that the women also suffered from increased prevalence of fatigue. Batliwala and Reddy (2003) also mentioned that the fatigue is due to various processes involved in the production of biomass fuel. Batliwala and Reddy (2003) thus support our study. Impairment in variables in menstrual cycle was observed in our study. The significant impairment in age of menarche (p<0.05), length of cycle (p<0.05), bleeding duration (p<0.05) and early menopause (p<0.05) were observed among exposed as compared to controls. There are also significant increasing trends in the prevalence as the exposure index increases. Exposure wise there are significant prevalence of impairment in length of cycle (p<0.05), amount flow (p<0.001) among subjects exposed for more than 51 hr-yrs when compared to exposed subjects 0- 20 hr-yrs and 21-50 hr-yrs. The significant prevalence
(p<0.05) of early menopause among subjects exposed for 21-50 hr-yrs was observed when compared to exposed subjects 0-20 hr-yrs and >50 hr-yrs.

In the present study, more than 70% kitchens were located inside the house without any proper ventilation. The combustion products of biomass fuel are retained in the houses for long time due to cooking. Combustion of biomass emits hundred of chemicals (Smith and Liu 1994; Wu et al., 2002) and pollutants with steroid-like activities e.g. fluorene, pyrene, dibenz [a,h] anthracene, indeno [1,2,3-cd] pyrene, benzo [a] anthracene, benzo [a] pyrene etc (Wu et al 2002; ICMR Bulletin 2001). These chemicals and pollutants with steroid-like activities act as endocrine disrupters (EDs). Long time exposure to these EDs acts as potential triggers which result in disrupting normal endocrine function among the female subjects of any age group leading to a change in hormonal activities. These EDs may disrupt hormones which are responsible for menstrual cycle and may alter the natural menstrual cycle (Stamati and Pitsos 2001) e.g. initiation of menarche, length of cycle, bleeding duration and abnormal/ excessive uterine bleeding. Stamati and Pitsos (2001) also support our findings. They mentioned that exposure to EDs was associated with menstrual cycle disorders. An epidemiological study of women who consumed fish from Lake Ontario showed a link between fish consumption, PCB exposure, and a reduction in menstrual cycle length. The study indicates the possible impact of PCB through food on menstrual cycle (Mendola et al, 1997).

A highly significant overall menstrual impairment (p<0.001) was observed among exposed (74.15%) as compared to controls (20.6%). This shows that there may be an association between pollutants with menstrual impairment. Menstrual impairment was also reported by Mondal (2009), which also supports
our study. This overall menstrual impairment might be due to the presence of EDs and other pollutants in BMF smoke either directly with steroid hormone receptors or indirectly through other metabolic pathways (Wu et al, 2002). The disturbance in normal endocrine function can lead to altered reproductive capacity, infertility, endometriosis etc (Wu et al, 2002). The majority of girls (73.5% in exposed and 86.3% controls) attain menarche around 15 years of age in this study. This proportion was similar to the earlier report among Higher Secondary School Girls (Lee et al. 2006) and study conducted by Sachan et al. (2012). Rest 26.5% exposed and 13.7% control attained menarche (before 11 years and above 16) (p<0.05). There is a significant difference (p<0.05), in long menstrual cycle (length of cycle) among the exposed (19.05%) as compared to the controls (9.8%). Mondal (2009) also reported significant (p<0.001) long menstrual cycle and significant (p<0.001) too irregular menstrual cycle among women exposed to biomass fuel. These women had 3.5 times more risk of having irregular menstrual cycle (p <0.001) (Mondal, 2009).

Birth outcomes are the important indicators of the health of the neonates and infants. In the present study, the adverse effect on pregnancy outcomes (still birth, miscarriage, congenital defect etc), neonatal and infant mortality due to BMF exposure was observed.

The results indicate that women who cook with biomass fuel (wood, dung, or crop residues) are more likely to have experienced a stillbirth than those who cook with clean fuel (LPG etc.). The prevalence of still birth (5.74%) as compared to controls (3.23%) indicates the increasing trends of adverse effects of bio mass fuel. The association between exposure to cooking smoke during pregnancy and significant increased risk of 50% of still birth among women
using biomass fuel during pregnancy was also reported by Mavalankar et al, (1991) [OR=1.5 (1.0-2.1)]. These provide further evidence that cooking with high-pollution unprocessed biomass fuels increases the risk of adverse pregnancy outcomes. Nearly 2 times greater risk of still births (OR=1.9, 95% CI=1.10–3.20) among pregnant women exposed to biomass smoke was also reported by Siddique et al. (2005). Recently Mondal (2009) reported that still birth is 5 times higher in biomass users. Very recently Lakshmi et al (2013) analysed the data of 188917 subjects of 2003-2004 District Level Household Survey-II of India and found the risks of stillbirths were significantly higher among women who used firewood for cooking as compared to LPG users (PR 1.48; 95% CI: 1.33–1.63; p<0.001). The risk of stillbirths was significantly raised among those who resided in rural areas. Our study also supports the earlier observation of still birth.

Glinianaia et al. (2004b) and Maisonet et al. (2004) also mentioned that air pollution is associated with increased adverse pregnancy outcomes. Mondal (2009) also reported association between menstrual cycle abnormalities and adverse pregnancy output. Tielsch et al (2009) also reported that exposure to biomass fuel was associated with increased risk of 6-month infant mortality. The findings of these authors strengthen my study.

The results indicate that significant mortality (p<0.05) was observed for neonates living in households that cooked with biomass fuel (Table 3.10). These results agree with previous studies performed at Sao Paulo, Brazil, showing the deleterious effects of air pollutants (Lin et al. 2004). Our results are consistent with the data of National Family Health Survey-3. Epstein et al (2013) analysed data of National Family Health Survey-3 and the results suggest the increased in
risk of neonatal death which is strongly associated with household use of coal (OR 18.54; 95% CI: 6.31-54.45) and perhaps with kerosene (OR 2.30; 95% CI: 0.95-5.55). These studies also support our study.

The results also indicate that women who cook with biomass fuel experienced highly significant infant mortality (p<0.001) than those who cook with clean fuel (Table 3.10). These results are consistent with the earlier study from Santa Ana, Ecuador linking biomass fuels to infant mortality in homes where biomass fuel is used (p=0.008) (Rinne et al., 2007). Wichmann and Voyi (2006) in a study showed that children in households using polluting fuel had a significant higher risk of mortality as compared to household using clean fuels. A highly significant (p<0.001) infant mortality was observed in exposure between 21-50 hr-yrs as compared to exposure >51 hr-yrs (Table 3.13). This shows that as the exposure increases, the infant mortality also increases. Lakshmi et al (2013) reported that biomass fuel smoke is a strongly associated risk factor for early infant death. The findings of the above authors support the present study. An association between exposure to ambient air pollution and adverse pregnancy outcome has also been reported by Dejmek et al. (1999), Wang et al. (1997), and Bobak and Leon (1999).

The results also indicate that increased mortality was observed for <5 yr (toddlers-1.25%, preschool children-0.25%) living in the households that cooked with biomass fuel as compared to household cooking with LPG. An unpublished analysis of a national health survey in India showed the significantly increased risk of mortality for children (<5 yrs of age) living in households that cooked with unclean fuels (Hughes and Dunleavy, 2001). Countries that used higher percent of biomass fuel for domestic energy also had a higher percent of infant
and child mortality (Smith and Mehta, 2003). Supportive evidence also comes from outdoor air pollution studies. Loomis et al. (1999) conducted a time series study of infant mortality in Mexico City in 1993-1995. They found the association between fine particles and the infant mortality rate (Loomis et al., 1999). These studies support our findings.

It is believed that the adverse effect is probably because of the increased concentration of carbon mono oxide (CO) in the indoor environment (Fig. 4.3). The significant association between biomass burning and stillbirths is consistent with the high amounts of CO contained in biomass smoke (Pokhrel et al, 2010).

**Fig 4.3-** How exposure to cooking smoke might cause still birth.
Biomass combustion in unvented cook stoves and chulha (earthen stove) produce large amount of CO which retained in the kitchen for the a long time in the poorly ventilated housed. This CO combines with hemoglobin, and forms carboxyhemoglobin (COHb). The COHb reduces the oxygen delivery to vital tissues (Townsend and Maynard, 2002) i.e. restricts oxygen delivery to maternal and fetal hemoglobin. The CO crosses the placental barrier. The hemoglobin in fetal blood has more affinity (approximately 10 times) for binding CO as compared to adult hemoglobin.

The elimination of CO from the fetal blood is slower than in the mother, which results in deprivation of adequate oxygen to fetus (Lakshmi et al., 2013). Due to insufficient volume of oxygen, the developing fetus results in restriction in growth and increases the risk of still birth and neonatal mortality.

In another mechanism proposed by Perera et al (1999) and Sram (1999), the fetuses are supposed to be highly susceptible to toxicants because of their exposure pattern and physiologic immaturity. The developing organ systems of fetuses can be more susceptible to environmental toxicants during sensitive periods of development because of the higher rates of cell proliferation or changing metabolic capabilities (Calabrese, 1986). Therefore, prenatal exposure to environmental pollution may result in adverse reproductive outcomes.

A significant decline in the air flow limitation of PEFR (p<0.05) and reduced FEV₁ was observed among women using biomass fuels for cooking compared to the women using cleaner fuels. A decline of 0.57 L/s air flow rate was observed for PEFR among women using biomass fuels compared to women using cleaner fuels. Deterioration in lung volume of 0.39 L/s for FEV₁ was observed among
women exposed to biomass fuels than their counterpart using cleaner fuels (Fig. 3.1).

PEFR was considered as a sensitive indicator for bronchial airway obstruction (Mridha et al., 2011). Hence decline in PEFR in the present study can be diagnosed as mild bronchial obstruction. The present study shows mild deterioration in lung function and air flow limitation among women cooking with biomass fuels. Our observation of decline in spirometric values was in consonance with the similar findings reported in an earlier study undertaken on women exposed to biomass fuels in rural areas of Mexico (Regalado et al, 2006). This denotes the lesser capacities of lungs among women.

The gases generated from the biomass fuels contain toxic materials including PAH (Zelikoft et al, 2002). The inhalation of PAHs during burning of biomass fuels can result in deteriorated lung capacities. Toxic particles like PAH and particulate matter (PM) emitted during burning of biomass fuels can penetrate into pharynx, trachea, bronchi, bronchioles and ultimately reach alveoli (Torres-Duque et al., 2008). The penetration and deposition of particles may have led to decline in airway status like PEFR among women exposed to biomass fuels in the present study (Torres-Duque et al., 2008). The toxic materials deposited in the airways can cause inflammation, mucous secretion and result in higher airway resistance which ultimately leads to decline in air flow rates (PEFR) and lung volume ($FEV_1$) as observed in the present study.

Women exposed to biomass fuel showed lower Forced Expiratory Volume in 1 Sec ($FEV_1$)/ Forced Vital Capacity (FVC) [$FEV_1$/FVC] ratios than women cooking with cleaner fuels (Regalado et al., 2006). The deterioration was diagnosed as mild type of lung function impairment (Regalado et al., 2006).
Earlier studied show that higher PM$_{10}$ concentrations in indoor air during cooking of biomass fuels can lead to reduction in FEV$_1$ and FVC, and increased prevalence of cough (Regalado et. al., 2006). Other studies (Dennis et. at., 1996, Dossing et. al., 1994) show high risk as per odds ratio with respect to chronic bronchitis and airflow obstruction in women exposed to wood smoke. The hematological findings were not found to be associated with BMF exposure except polymorphs (p<0.05). Though the prevalence of anemia is reported by Mishra and Retherford, (2007) among women exposed to biomass fuel. Similarly body composition showed the significant prevalence of underweight (BMI < 18.5 Kg/m$^2$) among biomass fuel users. These findings might be due to low socioeconomic status etc.

Serum analysis and urine analysis of exposed and controls show variations in values. But there is no significant association to biomass fuel exposure in our study. It is assumed that these minor variations of the serum and urine analysis are not attributable to biomass fuel exposure.

**4.1 Strength of the study:** The sample size of exposed and control subjects were representative samples for women of study location. The strength of the study was the higher duration of exposure of study subjects to biomass fuel and statistically large sample size in both groups. Therefore the study shows that the women exposed to biomass fuels for a longer duration can have various types of health impairments and deteriorated lung functions. The health problems of all organ systems and associated clinical, toxicological findings among women exposed to biomass fuel reported in the study are the highlights of the present thesis. The present study also discusses in detail the role of biomass fuel
exposure and associated health risks based on clinical, non invasive and invasive procedures and epidemiological approaches for the better understanding of the problem. The confounding factors like smoking, chewing of tobacco-related products, and medication were ruled out in the selection criteria of the subjects. To the best of my knowledge this is the first study to report on women exposed to biomass fuel and their menstrual problems which are discussed in details. Similarly infant and neonatal mortality were also discussed. Biomass fuels were used due to non-affordabity and unavailability of clean fuel. Thus the women were forced to use biomass fuels for daily energy needs which result in various types of health impairments and increase in disease burden of the country. Because these health problems the competent authorities should propose proper policy measures to the Government based on the present study. Further studies with large sample size in this target population are suggested for more insights into the problem. For lung function assessment longitudinal study is required to demonstrate whether or not any observed changes are variable, reversible, or progress to lung diseases (Diette et al., 2012).

4.2 Limitations of the study:

1. The parents of younger subjects did not give permission for invasive procedures e.g. withdrawl of blood for hematological parameters. We could not force them to do. So the numbers are reduced.

2. Few subjects were afraid to donate 5 ml blood. They withdrew their consent for blood examination.
3. Volunteered for the lung function test after a demonstration of the procedure of the test was included in the study. Those subjects who were not willing to face the lung function test were not forced for the study.

4. Body fat percent and visceral fat percent analysis are detected for age group above 18 yrs of age in the body fat analyser. Hence the BF% and VFL of subjects under this age group was not available for the study.

5. The menstruating subjects were exempted from collection of urine.