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

***Komala H.P. and Devi Prasad A.G.**
Department of Studies in Environmental Science, University of Mysore, Manasagangotri, Mysore-570006, Karnataka, INDIA

(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 (µg/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 µg/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.

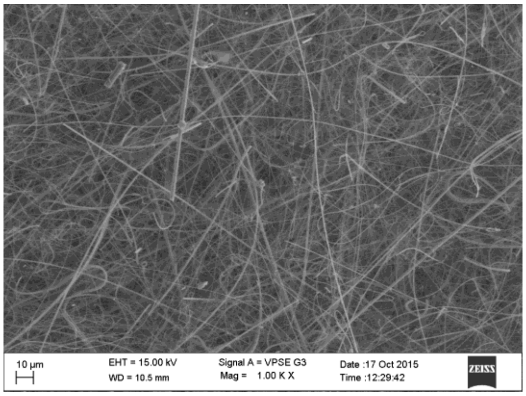
Table 1: Concentration of indoor air pollutants generated during cooking with different fuels in the rural households

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

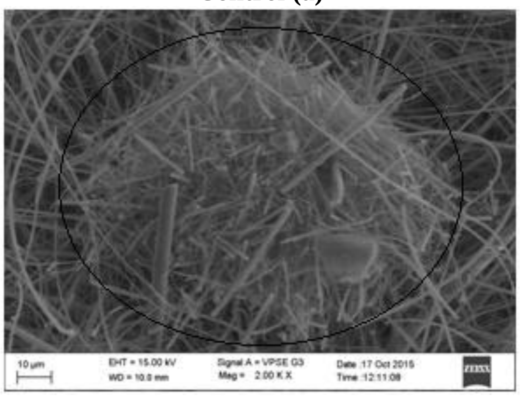
Table 2: Indoor air pollutants generated during usage different biomass cook stoves for cooking

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

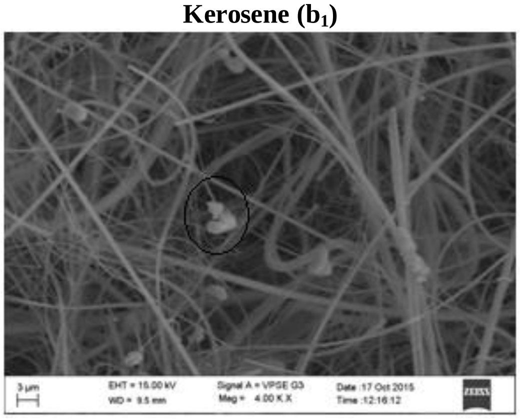
*Standard deviation



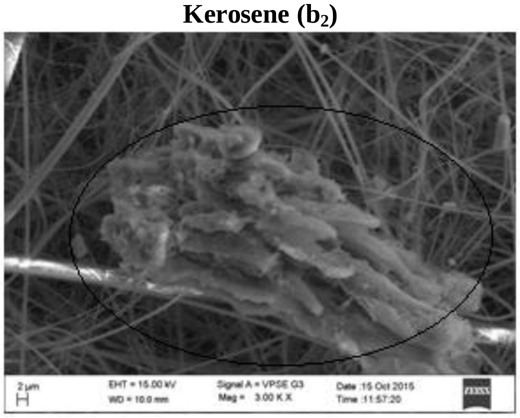
Control (a)



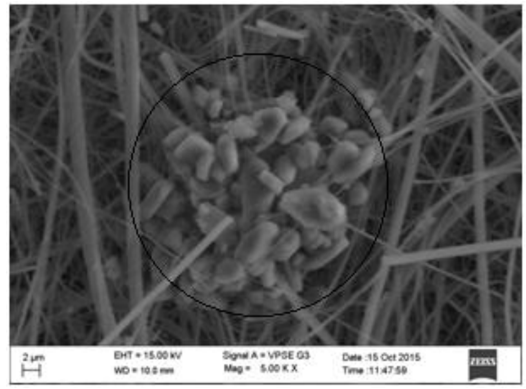
Kerosene (b_1)



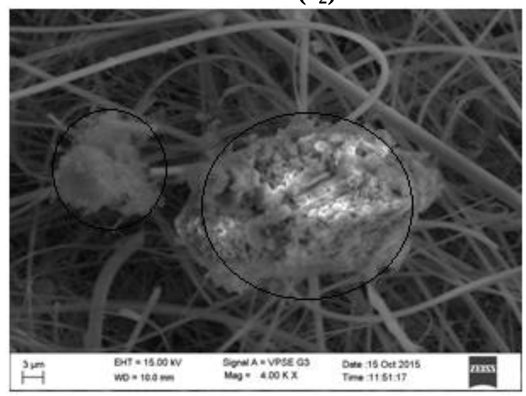
Kerosene (b_2)



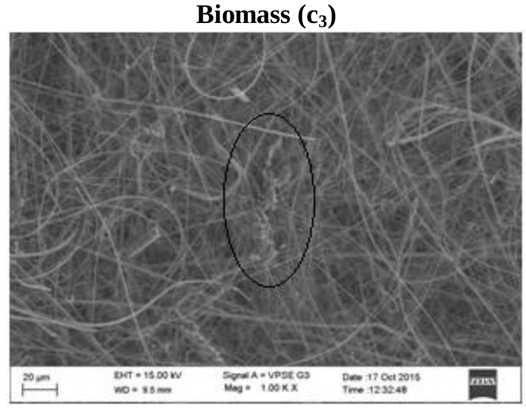
Biomass (c_1)



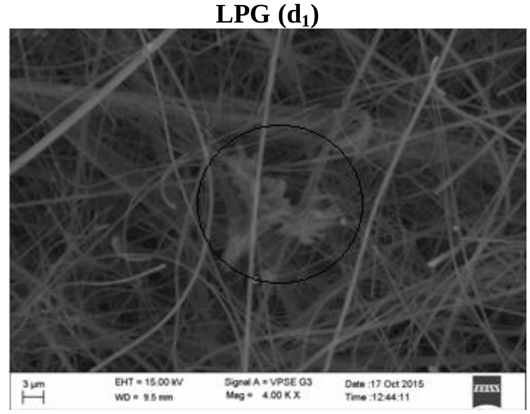
Biomass (c_2)



Biomass (c_3)



LPG (d_1)



LPG (d_2)

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**).