Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 4, Issue, 03, pp.092-097, March, 2012

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

DETERMINATION OF OUTDOOR (AMBIENT) AND INDOOR AIR QUALITY STATUS IN THE RURAL RESIDENTIAL ADJOINING JHANSI CITY

Yadav, Saurabh K.*, Kumar Vinit* and Singh M.M#

*Institute of Environment and Development Studies, Bundelkhand University, Jhansi- 284 128 (U.P.). India
#Department of Geology, Bundelkhand University, Jhansi- 284 128 (U.P.), India

ARTICLE INFO

Article History:
Received 15th December, 2011
Received in revised form
23th January, 2011
Accepted 29th February, 2011
Published online 31st March, 2012

Key words:
Indoor
Air Quality,
Outdoor air quality,
Pollutants,
Rural area.

ABSTRACT

Utilization of fuel-wood as a source of energy is a major source of indoor air pollution in the study area. Two villages nearby Jhansi City have been selected for the study purpose. Indoor and outdoor air quality in both rural residential areas has been monitored in winter, summer and monsoon seasons. In has been observed in the study that at all the selected sites, the average concentrations of the SPM and RSPM are high in winter in comparison to the summer and monsoon season. It was also noticed that SPM level at outdoor sampling sites in winter and summer the exceeds the prescribed limits as stipulated by central pollution control board (CPCB) New Delhi. The average concentration of SO_2 and NO_x were found below the permissible limits of CPCB at all the sites but NO_x concentration was higher than the outdoor NO_x concentration. SPM and RSPM were monitored through gravimetric method. West and Gaeke method was used for analysis of SO_2 (West and Gaeke, 1956) and Jackob and Hochheiser (1958) modified method for analysis of NOx. From the entire study it has been found that maximum families especially in rural area having improper ventilation and used of solid biomass.

INTRODUCTION

Indoor air pollution is a complex function of energy housing and behavioral factors. Indoor air pollution mediates the release of gases or particles into the air which are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emission from indoor sources and by not carrying indoor air pollutants out of the home. In our country air pollution studies particularly in rural households has so far been neglected. It is recently estimated that 82% of sulphur dioxide (SO_2), 38% of nitrogen dioxide (NO_2), 88% of volatile organic compounds and 96% particulate matter emissions in the country come from the household sector (Parikh, 1999). About three billion people still rely on solid fuels, 2.4 billion on biomass and the rest on coal, mostly in china (EPA, 2004 and Smith *et al*., 2004). Biomass is predominantly, though not exclusively a rural fuel indeed, in many poor African countries; Biomass is the main fuel for close to 1005 of rural homes. Marked socioeconomic differences (indicated by women's education) exist in both urban and rural areas. During the 1990s use of traditional fuels (biomass) in sub Saharan Africa increased as a percentage of total energy use; Although in most other parts of world the trend has generally been reverse (World Bank, 2002). Environmental Protection Agency's annual air pollution standard for PM_{10} is 50 mg/m 3 one to two orders of magnitude lower than levels seen in many homes in developing countries. During cooking when women and very young children spend most time in the kitchen and near the fire, much higher levels of PM_{10} have been recorded up to 30,000 mg/m^3 or more (Bruce *et al*., 2002). The concentration of indoor air pollutants coming out from combustion of biofuels such as wood, agriculture crops and dung cake used by rural households in developing countries causes several health problems especially to women and children below five years (Sarkar, 2004). It was observed that a major percent of rural households in developing countries still rely on biomass fuels (WHO, 1999) and about 75% of Indian households use biofuels for cooking purposes. The types of biofuel used by both rural and urban pupils are wood, straw, dung, charcoal, kerosene, gas and electricity. About 71% rural pupils used wood, straw and dung Thompson and Smith (Saksena *et al*., 2004) have recently compiled data on several of the main pollutants associated with various household fuels from studies of homes in a wide range of developing countries. Concentration of PM_{10} averaged over 24 hour periods were in the range 300 to 3000 (or more) microorganisms per cubic meter (mg/m^3). Relatively small-scale studies of indoor PM_{10} exposure from wood-fuel combustion have been conducted in Kenya (Boleij, *et al*., 1989, 36 households), Guatemala (Smith, *et al*., 1993, 60 households), Mexico (Santos-Burgoa, *et al*., 1998, 52 households), and Gambia (Campbell, 1997, 12 households), and indoor PM_{10} exposure from coal combustion has been conducted in Mongolia (Cowlin *et al*., 2005, 65 gers1). In addition, Balakrishnan, *et al*., have studied a larger sample of houses in rural India (Balakrishnan, *et al*., 2002,

***Corresponding author:** saurabh244009@gmail.com*

412 households; Parikh, *et al*., 2001, 436 households) and Baris *et al*. have studied a larger sample in China (Baris *et al*., 2006, 300 households). Biomass and coal smoke emits many health damaging pollutants including particulate matter (PM), carbon monoxide (CO), sulfur oxides, nitrogen oxides, aldehydes, benzenes, and polyaromatic hydrocarbon compounds (Smith, 1987). These pollutants mainly affect the lungs by causing inflammation, reduce ciliary's clearance and impaired immune response (Bruce *et al*., 2000). Rural areas suffer from air pollution caused by both natural as well as because of human activities. Air pollution from Natural causes occurs when contaminants drawn from animals, plants and land resources get disseminated in the atmosphere in normal course. Natural pollution also results from forest fire, coal fires, volcanic eruptions, dust storms and sand storms. Natural contaminants include spores, pollens, moulds, fur, feather, hair, dander, dust, grit and other types of particulate matter. Human activities like burning solid fuel indoors and tobacco smoking apart from agriculture, mining, coal processing and cement making produce high levels of pollution. Approximately 50% of the world's population and up to 90 % of rural household use biomass fuels as a domestic source of energy in the form of wood, crop residues and animal dung (World Resources Institute, UNEP, UNDP, World Bank, 1998-99). Cooking and heating with such solid fuels is the major source of indoor air pollution and pollution levels that exceed the allowable standard limits in developing countries (WHO/UNDP, 2004). Sulphur dioxide is a recognized pollutant because of its role in forming cold time smog (Hermann, 1991). It is acidic, irritant gas which in high concentrations can cause difficulties (Arch, 1954; Herman, 1961; Purnaendu, 1991; Mondal *et al*., 2011). People with asthma are more susceptible to the adverse effects of the gas as high concentrations may result in the fail of lung function in asthmatics and may lead to tight chest, coughing, wheezing and phlegm at high levels Sulphur dioxide (Ayodele and Abubakar, 2010). Thus, the current study aims to estimate the outdoor (Ambient) and indoor air quality of rural residential areas adjoining Jhansi city.

MATERIAL AND METHODS

The SO_2 and NO_x samplings were carried out by using a Handy Air Sampler (PEM-HAS 1B, Polytech Instrument) and SPM and RSPM were carried out by using a Personal Sampler (APM 800, Envirotech Instruments Pvt. Ltd.) in indoor monitoring. Outdoor air monitoring was done by Respirable Dust Sampler APM 460 with gaseous attachment APM 411. The measurements of SPM and RSPM were carried out twice a week at 8 hourly intervals for both outdoor and indoor location. Indoor gas and particulate matter measurement were carried out followed by outdoor air sampling at similar timing on the subsequent day. Gravimetric method was used for SPM and RSPM monitoring. West and Gaeke method was used for analysis of SO_2 (West and Gaeke, 1956) and Jackob and Hochheiser (1958) modified method for analysis of NO_x. The flow rate of the gas samplers were adjusted at 0.5 L min-1. Both the samplers were operated at 1 m above ground. For the present study, In rural residential area of adjoining village of Jhansi city, two sites namely Kochha bhavar and Lakara has been selected for outdoor (ambient) and indoor air quality monitoring. It was carried out during the winter (December 2009 to January 2010), Summer (April 2010 to June 2010) and monsoon (July 2009 to September 2009).

RESULTS AND DISCUSSION

WINTER

It was observed from Figure 1 that the average concentration of Outdoor (Ambient) suspended particulate matter during winter season at rural residential area viz. Kochha Bhavar and Lakara was 259.20 and 255.36 µg/m³ respectively and the average concentration of indoor suspended particulate matter during winter season at rural residential area viz. Kochha Bhavar and Lakara was 154.52 and 151.55 µg/m³ respectively. The outdoor ranged value of SPM in Kochha Bhavar and Lakara was 250.47 – 270.46 µg/m³ and 246.52 – 267.89 µg/m³ respectively. Similarly, the indoor ranged value of SPM in Kochha Bhavar and lakara was 140.12 – 172.12 µg/m³ and 137.22 – 169.32 µg/m³ respectively (Table 1). Similarly, the average concentration of outdoor respirable suspended particulate matter during winter season at rural residential area viz. Kochha Bhavar and Lakara was 121.49 and 119.31 µg/m³ respectively and the average concentration of indoor respirable suspended particulate matter during winter season at rural residential area viz. Kochha Bhavar and Lakara was 75.86 and 73.65 µg/m³ respectively (Figure 2). The outdoor ranged value of RSPM in Kochha Bhavar and lakara was 112.35 – 131.25 µg/m³ and 110.56 – 129.46 µg/m³ respectively. Similarly, the indoor ranged value of RSPM in Kochha Bhavar and lakara was 62.23 – 90.23 µg/m³ and 60.34 – 88.45 µg/m³ respectively (Table 2). It was also observed from Figure 3 that the average concentration of outdoor sulphur di oxide during winter season at rural residential area viz. Kochha Bhavar and Lakara was 13.47 and 13.37 µg/m³ respectively and the average concentration of indoor sulphur di oxide during winter season at rural residential area viz. Kochha Bhavar and Lakara was 11.06 and 9.72 µg/m³ respectively. The ranged value of outdoor SO_2 in Kochha Bhavar and lakara was 9.00 – 16.46 µg/m³ and 9.02 – 16.35 µg/m³ respectively and ranged value of indoor SO_2 in Kochha Bhavar and lakara was 7.57 – 12.55 µg/m³ and 7.22 – 12.23 µg/m³ respectively (Table 3). Similarly, the average concentration of outdoor nitrogen oxides during winter season at rural residential area viz. Kochha Bhavar and Lakara was 28.59 and 28.72 µg/m³ respectively and the average concentration of indoor nitrogen oxides during winter season at rural residential area viz. Kochha Bhavar and Lakara was 68.25 and 68.42 µg/m³ respectively (Figure 4). The ranged value of outdoor NO_x in Kochha Bhavar and lakara was 19.76 – 35.00 and 19.54 – 35.62 µg/m³ respectively. Similarly, the ranged value of indoor NO_x in Kochha Bhavar and lakara was 62.14 – 75.55 µg/m³ and 60.42 – 73.21 µg/m³ respectively (Table 4). UNEP / WHO (1995) agreed with statement that in many rural areas and in most cities, people in developing countries area exposed to a range of local, but strong, source of SPM.

SUMMER

It was observed from Figure 1 that the average concentration of Outdoor (Ambient) suspended particulate matter during summer season at rural residential area viz. Kochha Bhavar and Lakara was 204.64 and 201.95 µg/m³ respectively and the

Table 1: Concentration of SPM in rural residential areas

Seasons	Kochha Bhavar				Lakara			
	Indoor		Outdoor		Indoor		Outdoor	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Winter	140.12 – 172.12	154.52	250.47 –270.46	259.29	137.22 –169.32	151.55	246.52 –267.89	255.36
Summer	78.24 – 115.11	96.19	193.55 –220.18	204.64	73.14 –111.19	92.17	190.21– 218.78	201.95
Monsoon	68.54 – 97.56	80.4	146.32 – 175.62	162.04	68.67 – 95.78	79.25	144.34 – 171.64	158.56

Table 2: Concentration of RSPM in rural residential areas

Seasons	Kochha Bhavar				Lakara			
	Indoor		Outdoor		Indoor		Outdoor	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Winter	62.23 – 90.23	75.86	112.35 – 131.25	121.49	60.34 – 88.45	73.65	110.56 – 129.46	119.31
Summer	47.27 - 62.41	53.71	75.47 – 97.58	85.58	46.23 – 60.32	51.59	72.39 – 94.78	83.37
Monsoon	38.23 – 55.18	44.54	63.78 – 84.98	73.06	37.76 – 53.15	43.86	60.47 –82.46	70.45

Table 3: Concentration of SO_2 in rural residential areas

Seasons	Kochha Bhavar				Lakara			
	Indoor		Outdoor		Indoor		Outdoor	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Winter	7.57 – 12.55	11.06	9.00 – 16.46	13.47	7.22 – 12.23	9.72	9.02 –16.35	13.37
Summer	4.25 – 8.13	6.19	5.00 – 14.56	11.34	4.21 –7.78	6.02	4.76 – 14.67	11.36
Monsoon	3.56 – 7.15	5.36	5.26 –10.86	8.7	3.45 –7.78	5.61	5.32 –10.78	8.62

Table 4: Concentration of NO_x in rural residential areas

Seasons	Kochha Bhavar				Lakara			
	Indoor		Outdoor		Indoor		Outdoor	
	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Winter	62.14 – 75.55	68.25	19.76 – 35.00	28.59	60.42 –73.21	66.81	19.54 – 35.62	28.72
Summer	40.34 – 62.23	56.28	14.67 –28.32	24.43	42.56 – 65.55	54.05	14.72 – 28.39	24.42
Monsoon	35.65 – 46.21	40.93	14.00 –28.66	23.31	36.44 – 48.26	42.35	13.92 – 28.21	23.06

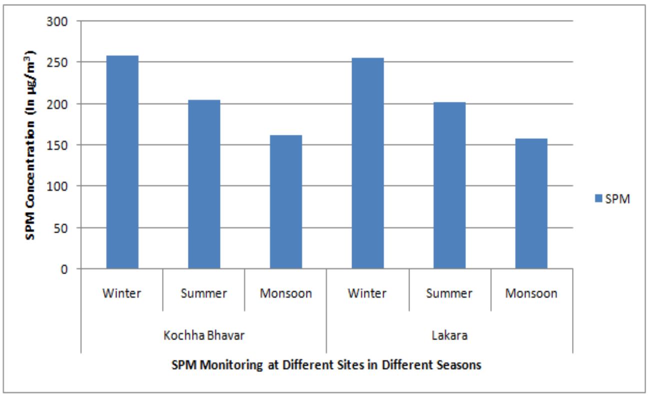

Figure 1: Showing the difference between Kochha Bhavar and Lakara SPM concentrations

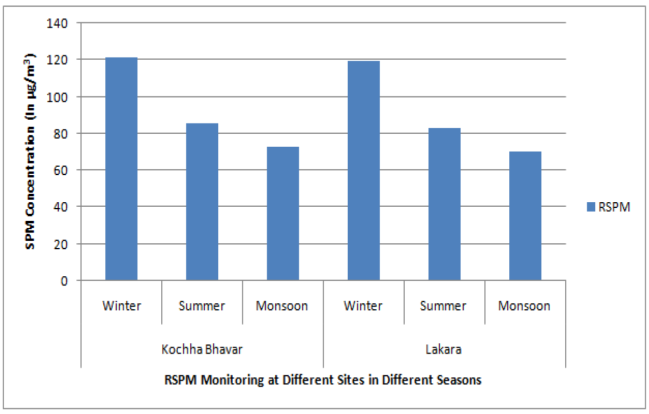

Figure 2: Showing the difference between Kochha Bhavar and Lakara RSPM concentrations

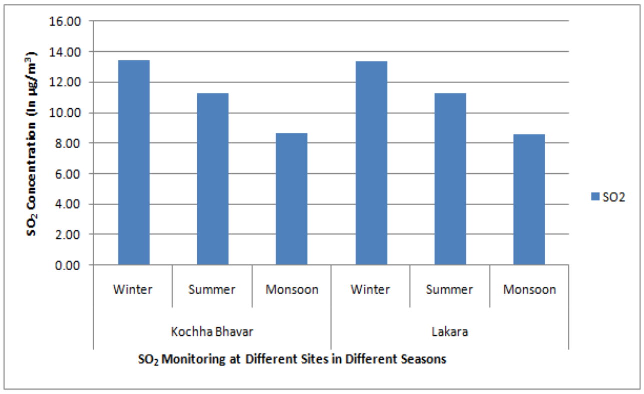

Figure 3: Showing the difference between Kochha Bhavar and Lakara SO_2 concentrations

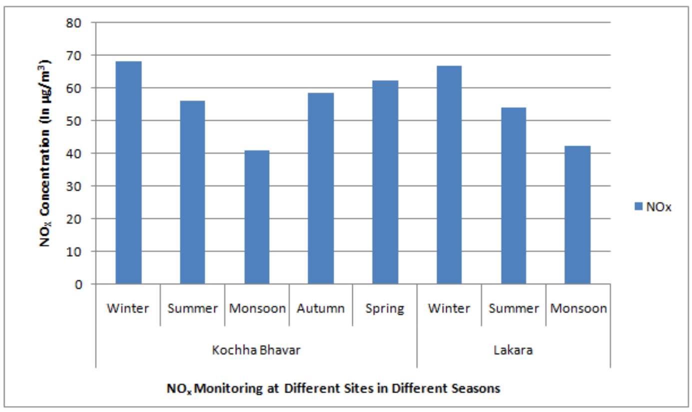

Figure 4: Showing the difference between Kochha Bhavar and Lakara NO_x concentrations

average concentration of indoor suspended particulate matter during summer season at rural residential area viz. Kochha Bhavar and Lakara was 96.19 and 92.17 µg/m³ respectively. The outdoor ranged value of SPM in Kochha Bhavar and lakara was 193.55 – 220.18 µg/m³ and 190.21 – 218.78 µg/m³ respectively. Similarly, the indoor ranged value of SPM in Kochha Bhavar and lakara was 78.24 – 115.11 µg/m³ and 73.14 – 111.19 µg/m³ respectively (Table 1). Similarly, the average concentration of outdoor respirable suspended particulate matter during summer season at rural residential area viz. Kochha Bhavar and Lakara was 85.58 and 83.37 µg/m³ respectively and the average concentration of indoor respirable suspended particulate matter during summer season at rural residential area viz. Kochha Bhavar and Lakara was 53.71 and 51.59 µg/m³ respectively (Figure 2). The outdoor ranged value of RSPM in Kochha Bhavar and lakara was 75.47 – 97.58 µg/m³ and 72.39 – 94.78 µg/m³ respectively. Similarly, the indoor ranged value of RSPM in Kochha Bhavar and lakara was 47.27 – 62.41 µg/m³ and 46.23 – 60.32 µg/m³ respectively (Table 2). It was also observed from Figure 3 that the average concentration of outdoor sulphur di oxide during summer season at rural residential area viz. Kochha Bhavar and Lakara was 11.34 – 11.36 µg/m³ respectively and the average concentration of indoor sulphur di oxide during summer season at rural residential area viz. Kochha Bhavar and Lakara was 6.19 and 6.02 µg/m³ respectively. The ranged value of outdoor SO_2 in Kochha Bhavar and lakara was 5.00 – 14.56 µg/m³ and 4.76 – 14.67 µg/m³ respectively and ranged value of indoor SO_2 in Kochha Bhavar and lakara was 4.25 – 8.13 µg/m³ and 4.21 – 7.78 µg/m³ respectively (Table 3). Similarly, the average concentration of outdoor nitrogen oxides during summer season at rural residential area viz. Kochha Bhavar and Lakara was 24.43 and 24.42 µg/m³ respectively and the average concentration of indoor nitrogen oxides during summer season at rural residential area viz. Kochha Bhavar and Lakara was 56.28 and 54.05 µg/m³ respectively (Figure 4). The ranged value of outdoor NO_x in Kochha Bhavar and lakara was 14.67 – 28.32 µg/m³ and 14.72 – 28.39 µg/m³ respectively. Similarly, the ranged value of indoor NO_x in Kochha Bhavar and lakara was 40.34 – 62.23 µg/m³ and 42.56 – 65.55 µg/m³ respectively (Table 4). Field test on wood burning stove and furnace reported elevated levels of CO, NO, NO_2, and SO_2 during the appliance operation (Traynor, *et al*., 1985; Knight, *et al*., 1985) and particulate matters (Oguntoke *et al*., 2010).

MONSOON

It was observed from Figure 1 that the average concentration of Outdoor (Ambient) suspended particulate matter during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 162.04 and 158.56 µg/m³ respectively and the average concentration of indoor suspended particulate matter during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 80.40 and 79.25 µg/m³ respectively. The outdoor ranged value of SPM in Kochha Bhavar and lakara was 146.32 – 175.62 µg/m³ and 144.34 – 171.64 µg/m³ respectively. Similarly, the indoor ranged value of SPM in Kochha Bhavar and lakara was 68.54 – 97.56 µg/m³ and 68.67 –95.78 µg/m³ respectively (Table 1). The average concentration of outdoor respirable suspended particulate matter during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 73.06 and 70.45 µg/m³ respectively and the average concentration of indoor respirable suspended particulate matter during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 44.54 and 43.86 µg/m³ respectively (Figure 2). The outdoor ranged value of RSPM in Kochha Bhavar and lakara was 63.78 – 84.98 µg/m³ and 60.47 – 82.46 µg/m³ respectively. Similarly, the indoor ranged value of RSPM in Kochha Bhavar and lakara was 38.23 – 55.18 µg/m³ and 37.76 – 53.15 µg/m³ respectively (Table 2). It was also observed from Figure 3 that the average concentration of outdoor sulphur di oxide during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 8.70 and 8.62 µg/m³ respectively and the average concentration of indoor sulphur di oxide during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 5.36 and 5.61 µg/m³ respectively. The ranged value of outdoor SO_2 in Kochha Bhavar and lakara was 5.26 – 10.86 µg/m³ and 5.32 – 10.78 µg/m³ respectively and ranged value of indoor SO_2 in Kochha Bhavar and lakara was 3.56 – 7.15 µg/m³ and 3.45 – 7.78 µg/m³ respectively (Table 3). Similarly, the average concentration of outdoor nitrogen oxides during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 23.31 and 23.06 µg/m³ respectively and the average concentration of indoor nitrogen oxides during monsoon season at rural residential area viz. Kochha Bhavar and Lakara was 40.93 and 42.35 µg/m³ respectively (Figure 4) . The ranged value of outdoor NO_x in Kochha Bhavar and Lakara was 14.00 – 28.66 µg/m³ and 13.92 – 28.21 µg/m³ respectively. Similarly, the ranged value of indoor NO_x in Kochha Bhavar and lakara was 35.65 – 46.21 µg/m³ and 36.44 – 48.26 µg/m³ respectively (Table 4). Various hotels/houses in Pune City were found to have higher NO_2 concentrations than the ambient air limit (Jayashree Mohan *et al*., 1992). Mandal *et al*. (1997) also studied indoor NO_2 concentrations in some residences of Calcutta and found annual average NO_2 concentrations well below the value prescribed by European countries.

Analysis data at different location of both the villages (Kochha Bhavar and Lakara) showed that Outdoor SPM values in Kochha Bhavar and Lakara exceeded the National Ambient Air Quality Standards in all the seasons, except monsoon seasons, While Indoor SPM concentrations were well within the standard in all the seasons in both the rural residential areas. The outdoor RSPM concentrations of both the rural residential areas were higher than the standard in winter, autumn and spring seasons, while it was well within the standard in summer and monsoon seasons and Indoor RSPM concentrations were well within the standard in all the seasons in both the rural residential areas. SO_2 and NO_x concentrations in both the rural residential areas at both sites (Indoor and Outdoor) were well within the standard but NO_x concentration in indoor monitoring sites at both the villages were higher than the outdoor concentration. Smith (2009) and Mac (2009) attested to high concentration of these parameters and other pollutants in rural areas where biomass energy is the primary source of energy. Mondal (2011) found that the maximum NO was in the fuel wood and minimum in the 2 carbon cake and the highest SPM was obtained in case of cow dung and the lowest in carbon cake and air pollution index was ranges from 23.793 - 95.239. Finally, it is strongly recommended that the people should not addicted in smoking inside the room and the common people should be aware about indoor air pollution through mass awareness program. Considering the negative consequences of indoor air pollution in rural areas, it is recommended that drastic measures be put in place so as to reduce the high level of pollution. Such measures should consider redesigning houses in rural areas to allow adequate ventilation, while cooking points should be located outside the dwelling units or separated from the dwelling units. A sustainable alternative source of energy that is readily available should be developed for the use of rural dwellers. Biogas is prominent among the possible energy sources that could be managed at the household level. Cooking stove with efficient combustion design should be introduced into the rural communities so as to minimize the emission of pollutants during cooking process. Outdoor SPM and RSPM concentration were high due to Natural contaminants like spores, pollens, moulds, fur, feather, hair, dander, dust, grit and other types of particulate matter as well as vehicular movement.

REFERENCES

Arch, S.H., 1954. A micro analytical method for the determination of sulphur dioxide in the atmosphere. Micro. Chem. Acta, pp: 668-678.

Ayodele, J.T. and F. Abubakar, 2010. Sulphur dioxide as indoor pollutant in Kano municipality Kano Nigeria. J. Environmental Chemistry and Ecotoxicol., 2(1): 9-13.

Balakrishnan, K., J. Parikh, S. Sankar, R. Padmavathi, *et al*., 2002, "Daily average exposures to respirable particulate matter from combustion of biomass fuels in ruralhouseholds of Southern India," Environmental Health Perspectives, 110(11): 1069-1975

Baris, E., S. Rivera, Z. Boehmova and S. Constatnt, 2006, « Indoor Air Pollution in Cold Climates : the Cases of Mongolia and China », ESAMP Knowledge Exchange Series, Note # 8. http:// www.ESMAP.org

Boleij, J. , P. Ruigewaard, F. Hoek, *et al*., 1989, "Domestic air pollution from biomass burning in Kenya," Atmospheric Environment, 23: 1677-1681.

Bruce, N. G., PerezPadilla,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), pp 1078–1092.

Bruce, N. G., Boy, E., and H. Delgado., 2002. "Birthweight and Exposure to Kitchen Wood Smoke during Pregnancy". Environmental Health Perspectives, 110 (1), pp109– 114.

Campbell, H., 1997, "Indoor air pollution and acute lower respiratory infections in young Gambian children," Health bulletin, 55: 20-31.

Cowlin, S.C., R.B. Kaufmann, R. Edwards and K. R. Smith, 2005, "Impact of Improved Stoves on Indoor Air Quality in Ulaanbaatar, Mongolia", ESMAP/ World Bank. nhttp://www.esmap.org/filez/pubs/31305MongoliaIAP09 0905forWeb.pdf

EPA (U.S. Environmental Protection Agency). 2004. Partnership for Clean Indoor Air, Washington, DC:EPA. http://www.epa.gov/iaq/pcia.html.

Herman, K., 1961. Effects of air pollution on human health. WHO Air Pollution Monograph Series, 46: 159-220.

Hermann, K., 1991. Handbook of Environmental Health and Safety: Principles and Practices. Lewis Publishers, Boca Raton, Florida, pp: 33431

Jacobs, M. B., and Hochheiser, S. (1958) Continuous sampling and ultra micro determination of nitrogen dioxide in air. Analyst Chem. 30: 426-428.

Jayashree Mohan, J., Gadgil, A. and Pawar, N.J. "Indoor air quality assessment at selected locations in Pune city", Indian J. Environ. Health, 1992, 34, 209–213.

Knight, C.V., Cooper, K.R. Alberti, R.R. and Ember, L.R. (1985), Indoor Air Quality Related to wood Heaters. In: Proceedings of IAQ '86 Managing Indoor Air for Health and Energy Conservation. American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta. pp 430-447.

Mandal, R., Thakur, S., Sen, B.K., Bandyopadhyay, I. and Sen, S. "Indoor nitrogen dioxide concentrations in some Calcutta residences", Indian J. Environ. Prot., 1997, 17, 99–102.

N.K. Mondal, S.K. Saha, J.K. Datta and A. Banerjee, 2011. Indoor Air Pollution: A Household Study in the Village Faridpur and Ranchi Colony, Durgapur, Burdwan District, West Bengal. World Journal of Environmental Pollution 1 (1): 05-07, 2011

Oguntoke, O., Opeolu B O., Babatunde N. 2010. Indoor Air Pollution and Health Risks among Rural Dwellers in Odeda Area,South-Western Nigeria. Ethiopian Journal of Environmental Studies and Management Vol.3 No.2.

Parikh, J., K. Balakrishnan, V. Laxmi, B. Haimanti, 2001, "Exposures from cooking with biofuels: pollution monitoring and analysis for rural Tamil Nadu, India, Energy 26: 949-962.

Parikh, K.S., (Ed.) 1999. India development report, Indira Gandhi Institute of Development, Oxford University Press, pp 85.

Purnaendu, K.D., 1991. Flourometric determination of atmospheric sulphur dioxide without tetrachloromercurate (II). Analytical Chemistry, 53: 2084-2087.

Rao C.S. (1993), 'Air Pollution', Wiley Eastern, New Delhi.

Santos-Burgoa, C., L. Rojas-Bracho, I. Rosas-Perez, A. Ramirez-Sanchez, G. Sanchez-Rico, S. Mejia-Hernandez, 1998, "Modelling particulate exposure and respiratory illness risk in a general population," Gaceta Medica Mexicana,134(4): 407-417.

Saxsena, S., Thompson, L. and Smith. K. R., 2004. "Indoor Air Pollution and Exposure Database: Household Measurements in Developing Countries http://ehs.sph.berkeley.edu/hem/page.asp?id=33.

Senthilnathan, T. and Rajan, R. D., 2003-b: ' Analysis of ambient air in Chennai city using air quality indexing method', Journal of Ecotoxicology and Environmental monitoring., Vol. 13, No. 3, pp. 175-178

Smith, K.R., 1987. Biofuels, Air Pollution and Health: A Global Review, Plenum Press, New York.

Smith, K. R., Mehta, S. and Feuz, M.., 2004. "Chapter 18: Indoor Smoke from Household Use of Solid Fuels." In Comparative Quantification of Health Risks: The Global Burden of Disease Due to Selected Risk Factors. Ezzati, M.., Lopez, A. D.

Smith, K., Y, Liu, J. Rivera, *et al*., 1993. "Indoor air quality and child exposures in highland Guatemala," Proceedings of the 6th International Conference on Indoor Air Quality and Climate, University of Technology, Helsinki, 1:441-446.

Traynor, G.W., Hamilton, M., Marbury, M., and Wanner, E.U (1985), Indoor Air Pollution due to Emissions from wood-burning stoves. LBL-17854 Lawrence Berkeley Laboratory, Berkeley, C.A. pp 264-281.

UNEP/WHO (1995).the potential of Human Exposure Assessment for Air Pollution. WHO/EHG/95.9.p.7

West, P. W., and Gaeke, G. C. (1956) Fixation of SOx as a sulfatomecurate (II) and subsequent colorimetric estimation. Analyst Chem. 28: 1816-1819.

WHO/UNDP, 2004. Joint Statement. Indoor air pollution -the killer in the kitchen. Geneva.

World Bank. 2002. "Energy Efficiency and Emissions." In World Development Indicators. Washington, DC: World Bank.Doctoral Project Report. Funded by University Grants Commission, India.

World Resource Institute, WHO, 1999. Guidelines for air quality, Geneva.

World Resources Institute, UNEP, UNDP, World Bank, 1998-99. World resources: a guid to the global environment, Oxford: Oxford University Press.

****