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ASSOCIATION OF HEAVY METALS COMPOSITION OF PARTICULATE MATTER WITH ENVIRONMENTAL TOBACCO SMOKE AND COOKING FUELS IN INDOOR AIR OF DELHI

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ABSTRACT
The present study was carried out in the industrial locations of Delhi with the primary objective to find out the association of heavy metals composition of suspended particulate matter (SPM) with environmental tobacco smoke (ETS) and cooking fuels in indoor air of Delhi, India. Indoor SPM level was measured by the handy air sampler and the concentration of heavy metals were determined in indoor SPM using atomic absorption spectrometer. The mean level of indoor SPM was 1080.0±482.4 $\mu g/m^3$. The Concentration of indoor SPM was greater in the houses where ETS exposure was recorded in the family, and where families were using biomass fuels for cooking. The heavy metals such as Cr, Co, Pb, Ni, Zn, Cu, Mo, Cd, were identified in indoor SPM. The mean level of Co and Pb was significantly higher in the houses where ETS exposure was noticed when compared to the houses without ETS exposure. Other heavy metals like Cr, Ni, Zn, Cu and Cd were also associated with ETS exposure in the houses. The mean level of Co, Ni, ZN, Pb, Cu, Mo and Cd were higher in the houses where families were using biomass fuels (coal, wood, cow dung cakes and kerosene) for cooking as compared to families using liquefied petroleum gas (LPG). This study revealed that ETS and biomass cooking fuels increased the concentration of SPM with heavy metals in the indoor environment. The high concentration of indoor SPM and heavy metals may be harmful for human health and may caused different types of diseases in the family members.

KEY WORDS: Indoor air pollution, SPM, ETS, biomass, LPG, heavy metals.

INTRODUCTION
A limited work has been undertaken in the recent past on the indoor air quality (IAQ) in non-occupational settings. However, it is suggested that elevated concentration of some airborne contaminants have been encountered in the indoor environments and considered as serious health hazards, need appropriate steps to protect human beings. Indoor air quality has more affects on human health, chiefly due to large amount of time we spend indoors in modern times. Jenkins *et al*. (1992) have observed that urban people spend on an average 87% times in indoors. Women and children are the most vulnerable as they spend more time indoors and are exposed to smoke. Airborne particulates reach ambient atmosphere and indoor air from a wide range of sources (Merefield and Stone, 1998). In general, concentrations of suspended particulate matter vary greatly from one area to another depending on the nature, intensity of local sources and temperature inversions (Abdul-Wahab and Yaghi, 2004). The main sources of indoor particulate matter are cooking, tobacco smoking, kerosene heating, wood burning, re-suspension of particles by people and pets, dusting & vacuuming, and by transport from outdoors via leakage through the walls, windows, or the ventilation system (Gulliver and Briggs, 2004; He *et al.,* 2004).
Environmental tobacco smoke (ETS) is a major source of indoor air contaminants and produce a huge amount of particulate matter in the air. The U.S. Surgeon General asserted in his report on *Smoking and Health* that tobacco smoke can be a significant source of atmospheric pollution in enclosed areas (Department of Health, Education, and Welfare, 1979). Tobacco use including both the smoking and the nonsmoking forms of tobacco is common in India. The few studies (Behera and Malik, 1987; Reddy and Gupta, 2004) on tobacco use in different population groups reported its prevalence from about 15% - 50% among men. Tobacco combustion in indoors contributes to concentrations of respirable particles, nicotine, polycyclic aromatic hydrocarbons, CO, acrolein, NO_2, and many other toxic substances (Reddy and Gupta, 2004). In the presence of cigarette smoke, many normal nonsmokers experience eye and throat irritation, headache rhinitis and coughing; allergic person report wheezing, sneezing and nausea as well. Particularly acute symptoms may be found in infants, children, persons with cardiovascular or respiratory diseases (Pope *et al*., 1995). Biomass fuel used for cooking which is another important source of indoor particulate matter and the use of wood and other forms of biomass as a cooking fuel is common in developing countries like India. In rural areas of India, biomass is used as the primary cooking fuel of households. Wood smoke contains hundreds of chemical compounds (Smith and Liu, 1994). Some of the components present in wood smoke which are concerned with the health include particles, polycyclic aromatic hydrocarbons and carbon monoxide (Samet *et al*., 1987). Exposure of air pollutants levels are usually much higher among women who tend to do most of the cooking (Behera *et al*., 1988) and among young children who stay indoors and who are often carried on

their mother's back or lap while cooking (Albalak, 1997).

Delhi, the capital city of India and the second largest commercial center in the South Asia has witnessed rapid growth in recent past, resulted in a significant increase in the environmental pollution. Rise in population and growth in economic activity has led to increase in the pollution in Delhi. It is undergoing rapid urbanization, industrialization and has become overpopulated and congested in the last couple of decades. Delhi is often categorized as a "service town"; however, industry is rapidly expanding. However, manufacturing industries in Delhi has also grown considerably as many consumer goods industries have established manufacturing units and headquarters in and around Delhi (Balachandran *et al*., 2000). The World Health Organization (2014) listed Delhi as world's most polluted city with respect to particulate matter ($PM_{2.5}$). Pandey *et al*. (2005) suggested that 30% of Delhi's population suffers from respiratory disorders due to air pollution and the incidence of respiratory diseases in the city is as high as 12 times of the national average. In Indian context, it has not been carried out such types of studies that find out the association of elemental composition of indoor particulate matter with environmental factors like environmental tobacco smoke & cooking fuels. The main aim of the present study is to find out the correlation between heavy metals composition of suspended particulate matter (SPM) and environmental factors like environmental tobacco smoke & cooking fuels in domestic air of Delhi, India.

MATERIALS & METHODS

Selection of study area

This study was conducted in Shahdara and Shahzada Bagh areas of Delhi, India. These study areas were selected as per Central Pollution Control Board (CPCB), India's premier pollution monitoring authority. The CPCB has established the National Ambient Air Quality Monitoring (NAAQM) Network at the national level and it was classified to Delhi in residential & industrial segments as per their pollution monitoring stations establishment (http://www.cpcb.nic.in). Shahdara and Shahzada Bagh are the industrial areas of Delhi. There are number of industrial units located in Shahdara and Shahzada Bagh industrial areas comprising industrial units of steel industries, chemical units, pickling units, copper wire drawing units, plastic units, engineering units and other small scale industries.

Sampling and analysis of indoor particulate matter

Indoor suspended particulate matter (SPM) levels were measured by using the Handy Air Sampler or Low Volume Sampler (APM 810, Envirotech Instrument Pvt. Ltd., New Delhi, India) with a flow rate of 1 liter per minute (Countess, 1974; ISO, 1983). Indoor SPM were collected on 25 mm Whatman glass microfiber filters. The filter papers were desiccated for 24 hours and weighted before sampling. Handy Air Sampler for indoor samples was placed in the center or corner of the room, with the inlet roughly 1 meter above the ground level. It was run continuously 6-8 hours of sampling period. At the end of the sampling period, the filter paper was removed. The filter papers were again desiccated for 24 hours then re-weighted to determine the mass of the particles collected. The particle concentration was measured by the weight gain of the filter divided by the volume of air samples.

Chemical analysis of indoor particulate matter

The heavy metals concentration in indoor suspended particulate matter were determined using Atomic Absorption Spectrometer (Shimadzu Make: AA-6300) (Shapiro, 1978; Lodge, 1988). The collected samples on filters were treated with dilute nitric acid (1% HNO_3 solution) to oxidize the organic matrix and to dissolve the metals present in the samples. Samples in batches of ten samples along with two blanks (to nullify impurities in the chemicals used) were digested simultaneously. The solutions were prepared and their volumes made up to 100 ml by adding double distilled water in a double screw capped polythene bottles. These solutions were stored in a refrigerator for major and trace elements analysis. The analysis is subsequently carried out by Flame Atomic Absorption Spectrophotometer (AAS). To obtain analytical precision and calibration, standard solutions (provided by Perkin Elmer) of known concentrations were used for each element.

Statistical analysis

The statistical analysis was performed on SPSS statistical software 10.0 (SPSS Inc, Chicago, IL version). The groups were compared for all variables using the "*Student t-test*" to compare equality for means and the 'chi square test' to compare category value. The differences were considered to be statistically significant at the $p < 0.05$ (two tailed test) or 5% level of significance (Grover and Rajkumar, 2008). Results so obtained are presented in percentage and mean ± SD.

RESULTS & DISCUSSION

During the present study, the survey team visited a total of 1103 houses in Shahdara and Shahzada Bagh industrial areas of Delhi but family member allowed for study in only 647 houses. A group of 33.8% houses were found to be exposed by environmental tobacco smoke (ETS) or passive smoking whereas, 70.3% family members were using liquid petroleum gas (LPG) for cooking, however, 29.7% family members mainly from lower class were using biomass fuels (kerosene, wood, coal and cow dung cakes) for cooking. As a result of excessive industrialization, urbanization and increased human activities, the air quality has been deteriorated significantly in most of the cities (Vijayanand, et al., 2008). In the present study, the mean concentration level of indoor SPM was 1080.0 ± 482.4 $\mu g/m^3$ in Shahdara and Shahzada Bagh industrial areas of Delhi. It was approximately 3 times higher than annual standard for industrial area that was set up by Central Pollution Control Board and 7 times higher than the WHO standards. High concentration of SPM was mainly due to the presence of a large amount of industrial establishment and high density of road traffic in these areas. Large scale construction activities such as metro rail, roads, flyovers & buildings may be also responsible for the high concentration level of particulate matter in Delhi. Cooking and smoking also play an important role to increase indoor SPM concentration in the houses. The high concentration level of indoor SPM may be harmful for the residents of the houses and may cause the different types of health illness chiefly respiratory diseases in the residents (Rajkumar *et al*., 2007 and 2008).

Correlation between indoor SPM and environmental factors

In the present study, a correlation between indoor SPM concentration level and environmental factors including ETS and biomass cooking fuels was established. ETS and biomass fuels are the main sources for the production of indoor particulate matter and its concentration is dependent upon the exposure level of the ETS and cooking fuels in the houses (Rajkumar *et al*., 2005; 2008). A good association between indoor SPM and environmental factors were observed in the present study and the mean level of indoor SPM was higher in the houses of Delhi (p=0.347) where ETS exposure was recorded in the family as compared to the houses without exposure of ETS (Table 1). The mean level of indoor SPM was also higher in the houses (p=0.231) where families were using biomass fuels (coal, wood, cow dung cakes and kerosene) for cooking as compared to families using LPG (Table 1).

TABLE 1: Correlation between indoor SPM and environmental factors in Delhi

Environmental Factors		Mean ±SD of indoor SPM ($\mu g/m^3$) in Delhi		
		Shahdara	Shahzada Bagh	Total
Environmental tobacco smoke (ETS)	Yes	1100.6±436.1	1137.2±510.7	1120.8±476.0
	No	1023.5±461.5	1090.2±511.8	1056.3±486.2
	p value	*0.408*	*0.604*	*0.347*
Fuel used for cooking	LP Gas	1009.4±422.0	1105.3±524.7	1056.1±475.8
	Biomass	1198.2±534.8	1116.9±478.9	1150.0±499.1
	p value	*0.137*	*0.912*	*0.231*

The composition of environmental tobacco smoke is similar to other fossil fuel combustion products that contribute to air pollution, and has been shown to be responsible for the increase in the indoor particulate matter in the houses (Repace and Lowrey, 1980). The concentration of various ETS constituents in an indoor space depends upon the number of smokers and their pattern of smoking, the volume of the space, the ventilation rate and the effectiveness of the air distribution, the rate of removal of ETS from the indoor air by air cleaners, deposition of particles onto surfaces, and surface adsorption and re-emission of gaseous components (National Research Council, 1986). On an average, a smoker of one pack of cigarette was estimated to contribute about 20 $\mu g/m^3$ of indoor air particles in 24 hours (Spengler *et al*., 1981).

Biomass and coal smoke contain large number of indoor airborne particulate matter. In many houses in developing countries, a major source of particulate matter is cooking smoke, caused by burning unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking and space heating (Bruce, 2000; Rajkumar *et al*., 2008). A study carried out by Boleij et al. (1989) in Kenya that measured domestic air pollution from biomass burning and found that the indoor respirable particles were 10 times higher (mean value 1400 $\mu g/m^3$) than the recommended air quality standard. In another study undertaken by Ezzati and Kammen (2001) in rural Kenya indicated that the SPM from biomass combustion was approximately 1000-2000 $\mu g/m^3$. The use of wood and other forms of biomass as a cooking fuel is common in developing countries such as India. In rural areas of India, biomass is used as the primary household cooking fuel and almost 90% of the energy used is accounted for by biomass (wood, 56%; crop residues, 16%; dung, 21%) (TERI, 1999).

Correlation between elemental composition of SPM and environmental factors

Some major and trace elemental concentrations in the atmosphere depending upon the environmental factors like environmental tobacco smoke and combustion of biomass and fossils fuels. Smoke of tobacco and unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking generate more than thousands of compounds where and several major and trace elements in the indoor atmosphere is present. Environmental tobacco smoke is a complex mixture of over 4000 compounds in particulate and vapour phases. They include more than 40 known or suspected human carcinogens, such as 4-aminobiphenyl, 2-naphthylamine, benzene, nickel, cadmium and a variety of polycyclic aromatic hydrocarbons (PAHs) and *N*-nitrosamines (Guerin, 1992). A number of irritants, such as ammonia, nitrous oxides, sulphurdioxide and various aldehydes, and cardiovascular toxicants, such as carbon monoxide, nicotine and some PAH compounds, are also present (Guerin, 1992). The combustion of biomass may also contain intrinsic contaminant a huge amount of trace metals in the environment (ICMR, 2001).

Present study identified the elemental composition of indoor SPM collected from the industrial areas of Delhi and found the heavy metals including chromium, cobalt, lead, nickel, zinc, copper, molybdenum and cadmium with high concentration. The mean concentration level of Cr, Pd and Cd was higher than World Health Organization and United State Environmental Protection Agency Standard. The high concentrations of airborne heavy metals representing a potential hazard to the population and may cause the health hazards in the family members.

In this context, Abdul-Wahab and Yaghi (2004) studied the total suspended dust and heavy metals emitted from an industrial workplace in Sohar Industrial Estate (SIE) in Oman and assessed the concentrations of Cr, Cu, Mn, Ni, Pb and Zn in the TSP. Richter *et al.* (2007) have determined the chemical fractionation in the airborne particulate matter (PM_{10}) from the Cerrillos monitoring station in Santiago, Chile and found the concentration of different elements such as Pb, As, Mo, Cd, Zn, Cr, V, Cu, Ba, Ca, Ti, Mn, Mg, Ni and Al in particulate matter. In India, Srivastava and Jain (2007) investigated the suspended particulate matter in indoor environment at Jawaharlal Nehru University (JNU), New Delhi. The indoor SPM concentration values crossed the 500 $\mu g/m^3$ level and sometimes were greater than 1000 $\mu g/m^3$. The AAS analysis carried out for the concentration of different metals such as Mg, Ca, Cu, Zn, Cd, Pb, Cr, Mn, Fe, Co and Ni, showed significant amount in the indoor SPM. Vijayanand *et al*. (2008) also assessed the heavy metal such as Zn, Fe, Cu, Pb, Ni, Cr and Cd in the ambient air of the Coimbatore city, Tamilnadu, India.

The association of heavy metals composition of indoor SPM with environmental tobacco smoke and biomass cooking fuels was established in the present study, and it was found that the mean level of Co and Pb was statistically significantly greater in the houses of Delhi, where exposure to family smoking or ETS exposure was present when compared to the houses without ETS exposure. The mean concentration level of Cr, Ni, Zn, Cu and Cd were also higher in the houses where family smoking or ETS was noticed but it was not statistically significant (Table 2).

TABLE 2: Correlation between heavy metals concentration in indoor SPM and environmental factors

Environmental factors		Mean concentration level of heavy metals *(ng/m³)* Cr	Co	Ni	Pb	Zn	Cu	Mo	Cd
ETS	YES	2021.93	195.09	1293.46	4523.77	15064.27	10346.69	4160.31	44.37
	NO	1777.41	143.62	1099.53	3181.29	14164.45	8370.60	4361.32	37.06
	P value	*0.192*	*0.035**	*0.091*	*0.001**	*0.266*	*0.188*	*0.809*	*0.220*
Fuel used for cooking	LPG	1887.71	164.43	1172.88	3575.62	13907.00	8660.12	3641.37	39.60
	Biomass	1869.75	167.77	1200.63	4108.03	15829.11	10316.57	4592.87	42.08
	P value	*0.927*	*0.892*	*0.834*	*0.227*	*0.018**	*0.274*	*0.315*	*0.704*

Abbreviation: * = *Statistically Significant*

The mean level of Zn was significantly higher in the houses where families were using biomass fuels (coal, wood, cow dung cakes and kerosene) for cooking as compared to families using liquid petroleum gas (LPG). The mean level of Co, Ni, Pb, Cu, Mo and Cd were also higher in the houses where families using biomass fuels for cooking when compared to LPG using for cooking, but it was not statistically significant (Table 2). It has been estimated that more than half of the world's households cook their food on the unprocessed solid fuels that typically release at least 50 times more toxic particulate pollutants than gas (Smith, 1990). The stoves or *chullah* used for cooking are not energy efficient. The fuels are not burned completely. The incomplete combustion of biomass releases complex mixture of organic compounds, which include suspended particulate matter, carbon monoxide, polyorganic material (POM), polyaromatic hydrocarbons (PAH) and formaldehyde. The biomass may also contain intrinsic contaminants such as sulphur and trace metals (ICMR, 2001).

CONCLUSION

This study was conducted in an attempt to identify the effect of the environmental tobacco smoke and biomass cooking fuels on the concentration level of suspended particulate matter and its heavy metals composition. Present study revealed that the mean level of indoor SPM was greater in the houses of Delhi where ETS exposure was recorded in the family, and where families were using biomass fuels for cooking. It was also revealed that the mean level of heavy metals such as Co, Pb, Ni, Zn, Cu and Cd were also higher in the houses where ETS was noticed in the family, and where the cooking was made on coal, wood, kerosene and cow dung cake when compared to LPG. Therefore, present study recognizes that ETS and biomass fuels are associated with the concentration level of SPM and its heavy metals composition. It is also proved that ETS and biomass fuels are one of them sources to the generation of particulate matter in indoor air and it increases the concentration of SPM with heavy metals in the indoor environment. The high concentration of indoor SPM and heavy metals may be harmful for human health.

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REFERENCES

Abdul-Wahab, S. A. and Yaghi, B. (2004) Total suspended dust and heavy metal levels emitted from a workplace compared with nearby residential houses. *Atmospheric Environment* 38, 745-750.

Albalak, R. (1997) Cultural practices and exposure to particulate pollution from indoor biomass cooking: Effects on respiratory health and nutritional status among the aymara Indians of the Bolivian Highlands. Ph.D. Thesis, University of Michigan, Ann Arobar, Michigan.

Balachandran, S., Meena, B. R. and Khillare, P. S. (2000) Particle size distribution and its elemental composition in the ambient air of Delhi. *Environmental International* 26, 49-54.

Behera, D., and Malik, S. K. (1987) Chronic respiratory disease in Chandigarh teachers. *Indian J chest Dis Allied Sci*. 29, 25-28.

Behera, D., Dash, S. and Malik, S. K. (1988) Blood carboxyhaemoglobin levels following acute exposure to smoke of biomass fuel. *India J. Med. Res*. 88, 522-42.

Boleij, J. S. M., Ruigewaard, P. and Hoek, F. (1989) Domestic air pollution from biomass burning in Kenya. *Atmospheric Environment* 23, 1677-1681.

Bruce, N., Perez-Padilla, R. and Albalak, R. (2000) Indoor air pollution in developing countries : A major environmental and public health challenge. *WHO Bull* 78, 1080-1092.

Countess, R. J. (1974) Production of aerosol by high volume samples. *J. Air Poll Cont Assoc.* 24, 605.

Department of Health, Education, and Welfare (1979) Smoking and Health A Report of the Surgeon General. Washington: U.S. Department of Health, Education, and Welfare, Public Health Service, Office of the Assistant Secretary for Health, Office on Smoking and Health. DHEW Publication No. (PHS) 79–50066.

Ezzati, M. and Kammen, D.M. (2001) Quantifying the effect of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries. *Environment Health Perspectives* 109, 481-487.

Guerin, M. R. et al. (1992) The chemistry of environmental tobacco smoke: composition and measurement. Chelsea, MI, Lewis Publishers.

Gulliver, J. and Briggs, D. J. (2004) Personal exposure to particulate air pollution in transport microenvironments. *Atmospheric Environment* 38, 1-8.

He, C., Morawska, L., Hitchins, J. and Gilbert, D. (2004) Contribution from indoor sources to particle number and mass concentrations in residential houses. *Atmospheric Environment* 38, 3405-3415.

ICMR (2001) *Indoor air pollution in India – A major environmental and public health concern*. Indian Council of Medical Research report, v.31(5).

ISO (1983). *Air quality-particle size fraction definitions for health-related sampling.* Tech. Report ISO/TR, 7708; 1983 (E). International Standard Association, Geneva, Switzerland.

Jenkins, P. L., Phillips, T. J., Mulburg, J. M. and Hui, S. P. (1992) Activity patterns of Californians: use of and proximity to indoor pollutant sources. *Atmospheric Environment* 34, 2603-2612.

Lodge Jr, J. P. (1988) Methods of air sampling and analysis (third edition). Lewis Publication, Inc. Michigan.

Merefield, J. R. and Stone, I. M. (1998) Environmental Issues in Opencast Mining, In: Proceeding of the Seventh International Symposium on Mine Planning and Equipment Selection/calgary/Canada: Mine Planning and Equipment Selection, edited by: Singhal R. K., pp.667-672.

National Research Council (1986) Committee on Passive Smoking. Environmental tobacco smoke: Measuring exposures and assessing health effects. National Academy Press, Washington, D.C.

Pandey, J. S., Kumar, R. and Devotta, S. (2005) Health risks of NO_2, SPM and SO_2 in Delhi (India). *Atmospheric Environment* 39, 6868-6874.

Pope III, C. A., Thun, M. J., Namboodiri, M. M., Dockery, D. W., Evans, J. S., Speizer, F. E. and Heath, C. W. (1995) Particulate air pollution as a predictor of mortality in a prospective study of US adults. *Am. J. Respir. Crit. Care Med.* 151, 669.

Raj Kumar, Nagar, J. K. and Gaur S.N. (2005) Indoor Air Pollutants and Respiratory Morbidity – A Review. *Indian J. Allergy Asthma and Immunol* 19 (1), 1-9.

Raj Kumar, Nagar, J. K., Kumar, H., Kushwah, A. S., Meena, M., Kumar, P., Raj, N., Singhal, M. K. and Gaur, S. N. (2007) Association of Indoor and Outdoor Air Pollutant Level with Respiratory Problems Among Children in an Industrial Area of Delhi, India. *Archives of Environmental and Occupational Health* 62 (2), 75-80.

Raj Kumar, Nagar, J. K., Kumar, H., Kushwah, A. S., Meena, M., Kumar, P., Raj, N., Singhal, M. K. and Gaur, S. N. (2008) Indoor Air Pollution and Respiratory Function of Children in Ashok Vihar, Delhi: An Exposure - Response Study. *Asia-Pacific Journal of Public Health* 20 (1), 36-48.

Raj Kumar, Nagar, J. K., Raj, N., Kumar, P., Kushwah, A. S., Meena, M. and Gaur, S. N. (2008) Impact of Domestic Air Pollution from Cooking Fuel on Respiratory Allergies in Children in India. *Asian Pacific Journal of Allergy and Immunology* 26, 213-222.

Reddy, K. S., Gupta P. C. (2004) Prevalence of tobacco use. Report on tobacco control in India. New Delhi: Ministry of Health and Family Welfare, Govt. of India. pp.49-56.

Repace, J. L. and Lowrey, A. H. (1980) Indoor air pollution, tobacco smoke, and public health. *Science* 208, 464-472.

Richter, P., Grino, P., Ahumada, I. and Giordano, A. (2007) Total elements concentration and chemical fractionation in airborne particulate matter from Santiago, Chile. *Atmospheric Environment* 42, 6729-6738.

Samet, J. M., Marbury, M. C. and Spengler, J. D. (1987) Health effects and sources of indoor air pollution. Part I. *Am. Rev. Respir. Dis.* 136, 1486-1508.

Shapiro, L. (1978) Rapid analysis of silicate, carbonate and phosphate rocks. *U.S. Geol. Sur. Bull.* 1401, 76p.

Smith, K. R. (1990) Indoor air quality and the population transition. In: Indoor Air Quality. Ed. H. Kasuga. Springer Verlag, Berlin, 448 p.

Smith, K. R. and Liu, Y. (1994) Indoor air pollution in developing countries. In: Samet JM, editor. Lung biology in health and disease, v.74: Epidemiology of lung cancer. New York: Marcel Dekker. pp.151-184.

Spengler, J. D., Dockery, D. W., Turner, W. A., Walfson, J. M. and Ferrish, B. G. (Jr) (1981) Long term measurements of respirable sulfates and particles inside and outside homes. *Atmospheric Environment* 15, 23-30.

Srivastava, A. and Jain, V. K. (2007) a study to characterize the suspended particulate matter in an indoor environment in Delhi, India. *Building and Environment* 42, 2046-2052.

TERI (1999) Tata Energy Data Directory Yearbook 1998-1999. Tata Energy Research Institute, New Delhi.

Vijayanand, C., Rajaguru, P. Kalaiselvi, K. Selvam, K. P. and Palanivel, M. (2008) Assessment of heavy metal contents in the ambient air of the Coimbatore city, Tamilnadu. *India. J. Hazardous Materials* 160, 548-553.

WHO (2014) *Ambient (outdoor) air pollution in cities database*. World Health Organization report 2014.