ISSN 0126-2807

Journal of Applied Sciences in Environmental Sanitation

Volume 4, Number 1: 55-62, January-April, 2009

Open Access http://www.trisanita.org

Research Paper

BLACK CARBON CONCENTRATION IN KITCHENS USING FIRE-WOOD AND KEROSENE FUELS

HARYONO S. HUBOYO*, ARIEF BUDIHARDJO and NURANDANI HARDYANTI

Environmental Engineering Departement, Faculty of Engineering Diponegoro University
Jl.Prof.Soedarto, SH Tembalang Semarang
*Corresponding Author: Phone: +62-024-76480678; Fax: +62-024-7460055; E-mail: huboyo@gmail.com

Received: 6th March 2009; Revised: 16th April 2009; Accepted: 27th April 2009

Abstract: In this study, the magnitude of black carbon (BC) in the kitchen was quantified in giving a preliminary picture about its potential on human health burden. BC concentration was derived from PM_{10} measurements by means of Smoke Stain Reflectometer quantifying during cooking and off-cooking. Sampled households was characterized by two groups i.e use wood and kerosene fuel each of which had been measured during cooking and off-cooking. The result of the research showed that the kitchen use fire-wood fuel in cooking condition, BC concentration were in the range $35.25 \pm 0,23$ to $83,803 \pm 0.37$ μg m^{-3}, while for off-cooking condition it showed 3.59 ± 0.06 to 8.98 ± 1.02 μg m^{-3}. In contrast, lower BC concentration was performed in kitchens use kerosene fuel where for cooking condition which it reached up to $6,90 \pm 0.06$ - $22,29 \pm 0.46$ μg m^{-3}, and it exhibited only $2,32 \pm 0.04$ - $5,74 \pm 0.1$ μg m^{-3} during off-cooking condition. The findings suggest black carbon concentration on average introduce high risk towards human health in cooking using fire-wood fuel.

Keywords: Reflectometer, PM_{10}, stove, cooking, households

INTRODUCTION

Air pollution is strongly associated with a number of adverse respiratory and cardiovascular health effects had been studied in many part of the world [1-3]. These effects are more pronounced for smaller particles pollutant [1]. Originally, energy use, development, air pollution, human and ecosystem health are all inextricably interrelated and energy generated by the combustion of fossil fuels and biomass often results in air pollution (both indoor and outdoor), with negative impacts on human and ecosystem health [4]. Indoor Air Pollution (IAP) ranks on 9 attributing on burden on disease (in daily adjusted life's years: DALY) worldwide from WHO database [5]. Based on current researches in developing countries, there are more risks with respect to exposure of IAP on population since dirty fuels usage combined with bad ventilation are common [6]. The level of indoor air pollution could be linked to how much fuel domestically is used. The share of energy consumption in the households sector in 1990 is 87.4 % for cooking, 8.9 % for lighting, and 1.3 % for other appliance, and 2.4 % for commerce & government [7]. Initially without source inside, the particle number concentration of indoor air pollution is consistently smaller than those for outdoor. With no notable indoor sources, and maybe some air conditioning, indoor PM concentrations ranged between 50 - 100% of outdoor concentrations [8].

Cooking activities is the most consume energy activities for households. Kerosene fuel is the most used cooking fuel in Indonesia before subsidized kerosene phase-out era recently. Their use incorporated with varying kitchen models in Indonesian urban households lead to complex problem for indoor air pollution. The size of indoor airborne particle generally less than that for outdoor due to unvaried its sources. Jankowska [9] found that most suspended particles in building was smaller than 10 μm. Sources related to household usually are cooking equipment (i.e. stove) which its varied emission is mainly determined by fuel used. The cleaner fuel used i.e LPG would emits lower PM concentrations rather than dirty fuel such as biomass burning [10]. Basics pollution from biomass fuel was particulate matter, particularly small particles ($PM_{2.5}$ – PM_1) and CO [11]. More detail, in the term of chemical characteristics, Bruce et al. [12] and Smith et al. [13] derived it globally as organics, an- organics. It could be derived detail as Soot (BC+OM), OM alone, SO_4^{2-}, metals, fly ash. By far, Beguma [10] reported that the major constituent of the PM emission was carbonaceous matter. Each chemical characteristic have a tendency to reside in certain size mode. For BC component the ratio of BC in fine particles is far greater than that of BC in coarse mode [13,14]. Numerous sources could emit hazardous BC, however the main indoor sources of BC were cooking and candle burning as studied in developed countries by [10] which contribute 16% and 31%, respectively, of the annual average indoor concentrations in the two years. Brunekreef [15] also pointed out that accumulation of combustion products would come up in the kitchen during cooking. Therefore, the indoor air pollutants from cooking smoke can be serious problem in the kitchens as well as other living room [16]. Moreover concentration levels of indoor air pollutants may vary significantly over time and space, this is due to the large variety of sources, the intermittent operation of some of the sources and the various sinks present. In case of diurnal variation of outdoor BC, Lou et.al [17] and Chatrapatty [18] found that in night-time period, the BC concentration exhibits higher concentration rather than in day time. Diurnal wind speed and temperature could be deemed as a reason for such phenomena. The indoor BC is also enriched by outdoor BC since penetration of outdoor particles take place in buildings mainly in high ventilated building. The contribution of outdoor particles (including BC) to indoor air pollutants were deeply studied elsewhere [16,19].

This study is aimed at quantifying the BC concentration during cooking and off-cooking period for kitchen using fire-wood and kerosene fuel. First hypotheses is that during cooking, the emission of BC was higher rather than that during off-cooking and the second one is that kerosene fuel would emit less pollutant than fire-wood fuel.

MATERIALS AND METHODS

Preparing Sampling Measurements

The air measurement for PM_{10} was conducted by means of Dust Medium Volume Sampler (DS 600-03). According to its operation manual for PM_{10} measurements the flow rate was set at scale 10 or equal to constant flow rate around 296 L min^{-1}. It stood about 1.2 m above ground, the MVS was set as such to reach breathing height of ordinary Indonesian women and it was taken placed approximately 1 m from the stove. It took around 1 hour for measure cooking activity and off-cooking activity as well. Glass microfiber filters (Whatman EPM 2000) were utilized as filter collection materials where each sample was provided co-located blank filter for control. Temperature and humidity was measured by Hygrometer (Hannna HI-9565), while for the barometric pressure using aneroid barometer. Moreover, the interview to inhabitants was run down for knowing the habitual activity and their health problem that might be caused by indoor air pollution.

Sampling Locations

Indoor air samples for this study were collected at two distinctive households groups in Bukit Kencana Regency of Semarang. First household group consists of 5 kitchens use fire-wood and the other group consists of 5 kitchens use kerosene as their fuel (Fig. 1). These samples were taken place in dry season beginning June to July 2008.

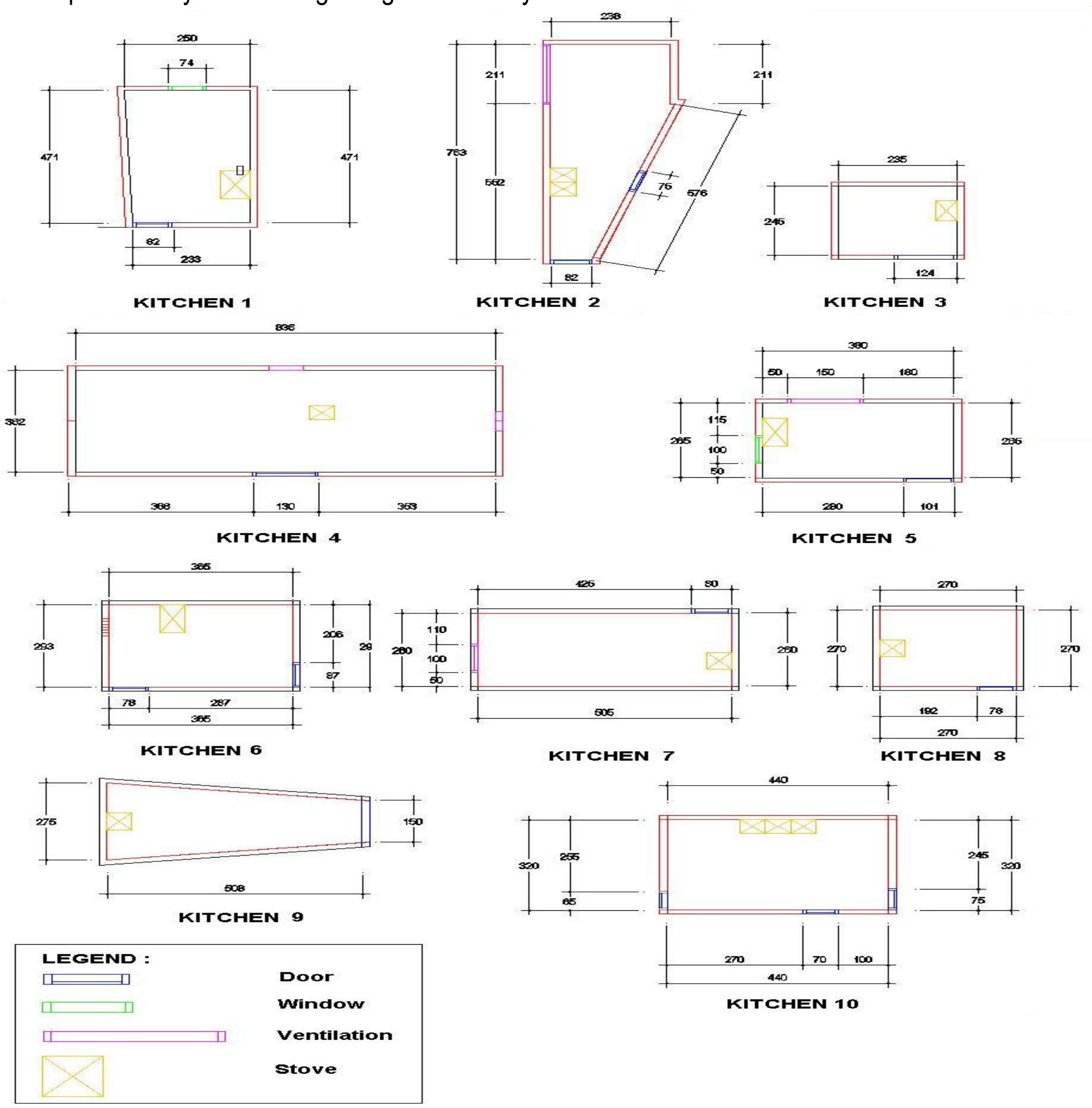

Fig. 1: Lay out of Sampled Kitchens

Analytical Methods

Prior to pre-sampling weighing and post-sampling weighing by a microbalance, the filters (samples and blanks) were desiccated at least for 24 h at room temperature (20 ± 5°C) using 5 digits balances (Mettler Toledo AG-245) within Radiometric Analysis Technique Laboratory in BATAN (National Nuclear Power Agency) at Bandung. For quantify BC, we used Smokestain Reflectometer (EEL MD43). Each sample has uncertainty derived from repetition measurements.

RESULTS AND DISCUSSION

Carbon Black Concentration

The measured concentrations of BC are presented in Table 1 for all the distinctive fuel used: fire wood and kerosene fuel. At the fixed-site, the monitored kitchen using fire-wood fuel showed the overall 1-hr average BC for cooking and off-cooking was 6.95μgm^{-3} and 62.48μgm^{-3} respectively. Lower BC concentration was recorded at these different houses using kerosene fuel showed the overall 1-hr average during cooking was 12.92 μg m^{-3} and 4.04 μg m^{-3} for off-cooking.,

Table 1: Black Carbon Concentration in the Sampled Kitchens

Fuel used	Black Carbon Concentration (μg m^{-3})	
	Cooking	Off-cooking
Wood	35,25 ± 0,23	8,16 ± 0,02
	70,59 ± 1,39	7,20 ± 0,05
	52,59± 0,22	6,79 ± 0,1
	83,80 ± 0,37	3,59 ± 0,06
	70,16 ± 0,07	8,98 ± 1,02
Kerosene	13,81 ± 0,11	2,32 ± 0,04
	11,33 ± 0,14	4,40 ± 0,06
	6,90 ± 0,06	5,74 ± 0,1
	22,29 ± 0,46	4,58 ± 0,03
	10,22 ± 0,06	3,15 ± 0,06

BC which is a product of incomplete combustion is an indicator of the unburned element carbon. The higher concentrations during cooking both for fire-wood and kerosene fuel rather than off-cooking indicates that cooking activity produce BC in certain proportion. In fire-wood fuel, its production during cooking almost ten folds rather than off-cooking while it shows only ten times for kerosene fuel. From this research it seems that burning vegetation (biomass burning) produce more BC rather than fossil fuel. Earlier study as studied by Mayol-Bracero et al [20] suggest that major component of airborne particles (including BC) produced by burning vegetation besides diesel vehicle exhaust. Nevertheless, other research result revealed that BC didn't have significant contribution to indoor air [21]. The BC concentrations were somewhat higher than those in Hongkong [19] appearing 2.8 μg m^{-3} for 24-hr measurement and however, the results are comparable to measurements in Thailand [22] showing 8 – 11 μg m^{-3}. Based on comparison steps in Table 1, our study results confirmed our first exploratory hypotheses that during cooking, the emission of BC was higher rather than during off-cooking. In this case, in the course of cooking using for fire-wood and kerosene fuel the difference concentration between cooking to off-cooking reached up to 76.84% and 83.17% respectively. On incomplete natural burning, many undesired pollutant would arise due to its complex phenomena [23]. So as to minimize the emission, it wise to use environmental-friendly cook stove, as studied by Roden [19] that in well-designed improved cook stoves combining with chimney establishment, it can significantly reduce the emission factors below traditional cook stoves. Yet elevated concentration of indoor pollutant because of stove age should be considered too [24].

The second hypotheses that kerosene fuel would emit less than fire-wood fuel was proven as depicted in Table.1. Since during off-cooking there no significant difference on BC concentration for all samples, it could be assumed that no visible difference with respect to food preparation inter-houses use kerosene and fire-wood fuel. Therefore, roughly, it could be noted that by using kerosene fuel it would reduce the emission to almost 80%. This is valuable results in order to minimize burden of indoor air pollution. By shifting fire-wood to kerosene even LPG will reduce mostly indoor air pollution with respect to energy ladder toward pollutants emission as described by Smith [6]

BC proportion in PM_{10} and Sampled Kitchens Characteristics

Figure 2 shows that on average BC exited in PM_{10} during cooking for fire-wood and kerosene fuel used were 0.0081% and 0.0093% respectively. These values were far below what Roden [25] did in improved cookstoves that BC was averaged about 25% of PM. Also from Goldberg [26] study in Germany which stated that BC in TSP occupy nearly 4%.

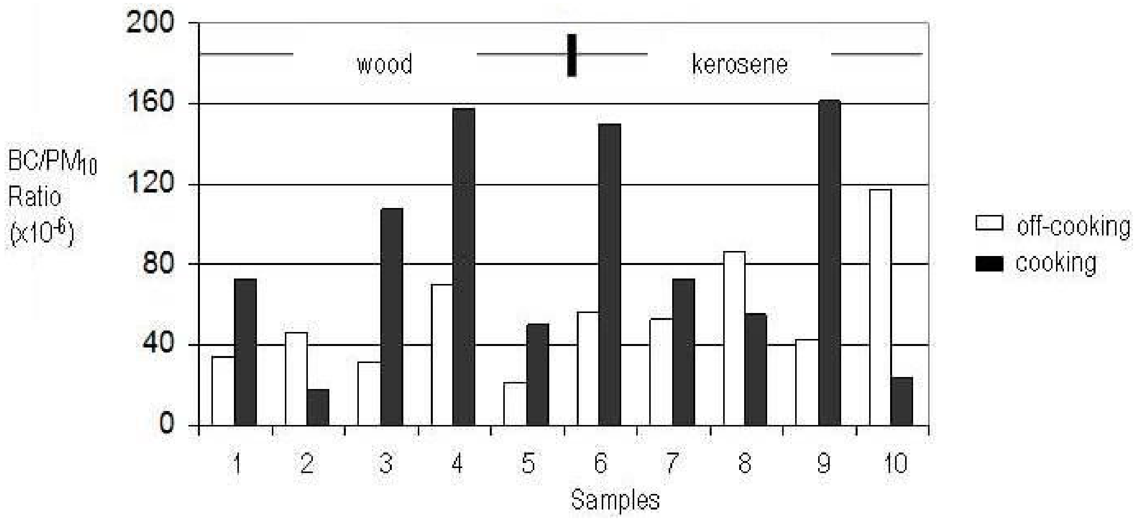

Fig. 1: Ratio of Black Carbon to PM_{10}

Field observation revealed that the opening space of ventilation in sampled house kitchens were around 1.612 – 3.672 m^2, while the kitchens volume lied in 16.121 – 95.328 m^3. In detail, the lay out of all kitchens are depicted in appendix figure. Refer to ideal ventilation for the room by Tantasavasdi [26] by using ratio of ventilation area to floor area should be minimum 40%, these kitchen characteristics fail to comply the standard. For houses using fire-wood fuel, their temperature during cooking condition were recorded in the range 26.4° - 34.2°C and its still relatively unchanged during off-cooking which showed 26.7° - 34.8°C. Average room temperature during cooking in the kitchen is commonly around 30°C [8]. Therefore mirror to this study, it's acceptable situation. Similar condition was performed for houses using kerosene fuel. The relative humidity (RH) lied between 44.95% to 74.9% for houses using fire-wood fuel during cooking and on average it reduced about 17.6% after cooking. Whereas for houses using kerosene fuel, the relative humidity appeared in the range 41.75% - 61.2% when they conducted cooking and there weren't notable change this RH after cooking. Many housing providers state that ideal RH for common room is 40% - 60%, nevertheless for tropical climate as for Indonesia, the appearing RH in this study is tolerable [27].

In summary, this is the preliminary study to account BC concentration in the houses particularly in the kitchen. It is interesting that some of Indonesian people, especially in rural areas shift their kerosene consume energy to dirtier energy due to unreachable of LPG price for poor after subsidized kerosene phase-out. This phenomena should be taken into account combining other effort to reduce indoor air pollution such as install improved cookstove – chimney, implement environmentally-kitchen design and good maintenance of the stove as well as good cooking behaviour. Likelihood, if particle emissions are able to be reduced, ultimately BC concentration could be reduced too, hence reduce possibility of cancer in humans with regard to BC is defined as carcinogenic 2B class. Continuous real-time observation will be helpful to understand the fate of BC in the house (in the kitchen for precisely) so as to improve our understanding of its effects.

CONCLUSIONS

Concentration of BC in the kitchen of the households using fired-wood fuel during cooking were higher than those in the household using kerosene fuel. While during off-cooking there is notable difference of BC concentration, it might they have typical sources of BC emission without stove. Using kerosene fuel or even other cleaner energy would have clear benefits in reducing BC emission in particular and indoor air pollution as a whole.

Acknowledgements: This study was supported by Cluster Research Group on Low Cost of Sanitation Technology, Faculty of Engineering Diponegoro University. Dr.Muhayatun in BATAN is gratefully acknowledged for providing the analytical instruments. Thanks to Dini and Anggrika for technical support.

References

1. Chauhan, Anoop J and S. L Johnston. 2003. Air pollution and infection in respiratory illness. British Medical Bulletin; 68: 95–112
2. Maynard, R.L and I. Myers, 2005. Polluted air—outdoors and indoors, Occupational Medicine. 55:432–438, Oxford University Press.
3. Smith Kirk R, Jonathan M Samet, Isabelle Romieu and Nigel Bruce. 2000. Indoor air pollution in developing countries and acute lower respiratory infections in children , Thorax; 55;518-532,
4. UNEP. 2006. Feature Focus Energy and Air Pollution, GEO Year Book 2006 UNEP
5. Smith, K R. 2005. Indoor Air Pollution : Update on the Impacts of Household Solid Fuels, Environment Matters 2005 — The World Bank Group
6. Smith, K R and Sumi Mehta. 2003. The burden of disease from indoor air pollution in developing countries: comparison of estimates. International Journal of Hygiene and Environmental Health, 206(4-5): 279-289

7. UNEP. 1999. Economics of Greenhouse Gas Limitations, Country Reports : Indonesia Country Study, Ministry of Environment Republic of Indonesia
8. Panyacosit, Lily. 2001. A Review of Particulate Matter and Health: Focus on Developing Countries (Interim Report), International Institute for Applied Systems Analysis International Institute for Applied Systems, Schlossplatz 1 A-2361 Laxenburg Austria
9. Jankowska, E; D. Kondej; T. Jankowski and M. Gliñski. 2005. Fine Particles Present in Indoor Air, Poster Dept of Chem. and Aerosol Hazards, CILP – National Research Institute, Czerniakowska 16, 00-701 Warsaw, Poland
10. Beguma B.A; S. K. Paul, M. D Hossain; S. K. Biswasa and P. K. Hopke, 2009. Indoor air pollution from particulate matter emissions in different households in rural areas of Bangladesh., Building and Environment, 44 (5): 898-903
11. WHO .2005. Workshop Resources: Indoor Air Pollution and Household Energy Monitoring, WHO Press, 20 Avenue Appia, 1211 Geneva 27, Switzerland
12. Bruce, N, Rogelio Perez-Padilla & Rachel Albalak. 2000. Indoor air pollution in developing countries: a major environmental and public health challenge, Bulletin of the World Health Organization. 78 (9)
13. Fromme H; T. Lahrz; A. Hainsch; A. Oddoy; M. Piloty and H. Rüden. 2005. Elemental carbon and respirable particulate matter in the indoor air of apartments and nursery schools and ambient air in Berlin (Germany). Indoor Air. 15 (5) : 335 - 341
14. Smith, K R .2002., Indoor air pollution in developing countries: recommendations for research, Indoor Air Journal; 12: 198–207
15. Moloi K, Chimidza S, Lindgren E S, Viksna A and Standzenieks P, 2002. Black carbon, mass and elemental measurements of airborne particles in the village of Serowe, Botswana. Atmospheric Environment, 36(14): 2447–2457
16. Brunekreef B; S.M Willers; M. Oldenwening; H. A. Smit; M. Kerkhof and H. De Vries. 2005. Gas cooking, kitchen ventilation, and exposure to combustion products, Indoor Air. 16 (1), pp 65 – 73, 2005, Blackwell Munksgaard
17. Dasgupta, S; D. Wheeler; M. Huq and M. Khaliquzzaman, 2009. Improving indoor air quality for poor families: a controlled experiment in Bangladesh, Indoor Air, 19: 22–32
18. Lou, Shujuan; Mao Jietai and Wang Meihua. 2007. Observation of black carbon aerosol in Beijing 2003, Front. Environ. Sci. Engin. China., 1(3): 345–349 Higher Education Press and Springer- Verlag.
19. Chatrapatty, Bhugwant and Philippe Brémaud. 2001. Simultaneous Measurements of Black Carbon, PM10, Ozone and NOx Variability at a Locally Polluted Island in the Southern Tropics, Journal of Atmospheric Chemistry 39: 261–280. Kluwer Academic Publishers.
20. Lee, S.C; J.J Cao; J. C. Chow; Y. Cheng; K. F. Ho; K. Fung; S. X. Liu and J. G. Watson. 2005. Indoor/outdoor relationships for PM2.5 and associated carbonaceous pollutants at residential homes in Hong Kong – case study, Indoor Air, 15 (3), 197 – 204
21. Mayol- Bracero, O. L; Guyon P; Graham B; Andreae MO; Decesari S and Facchini MC. 2002. Water-soluble organic compounds in biomass burning aerosols over Amazonia-2. Apportionment of the chemical composition and importance of the polyacidic fraction. J Geophys Res 107(D20):8091
22. Kwangsam, Na and David R. Cocker. 2005. Organic and elemental carbon concentrations in fine particulate matter in residences, schoolrooms, and outdoor air in Mira Loma, California Atmospheric Environment. 39 (18) : 3325-3333
23. Oanh, N.T.Kim, Aungsiri Klinmalee and Kasama Srimongkol. 2008. Indoor air pollution levels in public buildings in Thailand and exposure assessment, Environ Monit Assess, Springer Science Business Media B.V. 2008, DOI 10.1007/s10661-008-0507-z
24. Cheremisinoff, N. P. 1980. Wood for energy production, Research and Engineering Co., Florham Park; New Jersey Institute of Technology, Newark, N.J., Ann Arbor Science Publishers, Inc., 1980. 159 p.

25. Naeher L.P, B. P.Leaderer and K. R. Smith. 2001. Particulate Matter and Carbon Monoxide in Highland Guatemala: Indoor and Outdoor Levels from Traditional and Improved Wood Stoves and Gas Stoves, Indoor Air, 10 (3), 200 – 205
26. Roden Christoph A; T.C. Bond; Stuart Conway; A.B.O Pinel and Nordica MacCarty. 2009. Dean Still Laboratory and field investigations of particulate and carbon monoxide emissions from traditional and improved cookstoves. Atmospheric Environment. 43 (6): 1170-1181
27. Goldberg, E. 1972. Black Carbon in the Environment. Wiley and Sons, New York.
28. Tantasavasdi, C., Srebric, J., and Chen, Q. 2001. "Natural ventilation design for houses in Thailand," Energy and Buildings, 33 (8): 815-824.