Does the kitchen location matter? Comparing PM in buildings in Irasa Community of Ado Ekiti, Nigeria

Oluwakemi Akintan, Ekiti State University, Ado Ekiti, Nigeria

The European Conference on the Social Sciences 2016
Official Conference Proceedings

Abstract

Predominate cooking fuel in majority of developing countries continues to be biomass fuel (agricultural wastes, wood, charcoal, sawdust, wood chip). In most cases, cooking is done on open fires and the incomplete combustion of the fuel during this process releases harmful pollutants into the atmosphere. Exposure to by-products of cooking fuels is a major global health concern and the altering of the cooking environment is not enough to improve air quality in developing countries. In peri-urban areas of Ado Ekiti, Nigeria, particulate matter levels were measured in buildings of householders; these comprised of nine indoor and nine outdoor kitchen locations. $PM_{2.5}$ was monitored continuously for seven days at each building for nine weeks using the UCB monitor. Average 24 hour mean of $PM_{2.5}$ levels for indoor kitchen location ranged between 48 $\mu g/m^3$ and 648 $\mu g/m^3$, while it was between 42 $\mu g/m^3$ and 275 $\mu g/m^3$ for outdoor kitchen locations. Households' survey during cooking activities show that smoke infiltrated into buildings through eaves. The wafting around of the smoke and overnight retaining of fire in the hearth further compromised building air quality, and made the WHO daily average of 25 $\mu g/m^3$ for $PM_{2.5}$ to be exceeded. There is a wide gap between guidelines and the real air quality levels in buildings regardless of the kitchen location. Therefore, measures at reducing indoor air pollution should not only focus on cooking fuel for indoor kitchens, but all other kitchen types and locations must be considered as well.

iafor
The International Academic Forum
www.iafor.org

Introduction

Households subsisting on biomass fuels would continue to be on the increase and according to OECD/IEA (2011) over 2.6 billion people by 2030 would still be relying on biomass fuels for domestic energy. With high number of people still and/or would be dependent on biomass fuels in developing countries, the by-product of indoor air pollution would continue to diminish the quality of life in these areas (World Energy Assessment, 2000). With the short and long term adverse health impact of exposure to biomass fuel smoke on end-user, there is growing international concern to accessing clean energy.

The burden of indoor air pollution are mostly felt in developing countries where households subsist on biomass fuels (agricultural wastes, wood, charcoal, sawdust, wood chip) for domestic activities (Bruce *et al*., 2013). The use of biomass fuels to meet domestic energy needs in developing countries has been contributing to high levels of indoor pollution. These widely used household fuels by more than 80% of rural households in Sub-Saharan Africa largely remains an important source of exposure to particulates (UNDP, 2009). The inefficient burning of these fuels over open fires produces high emissions which include but not limited to carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAHs), sulphur dioxide (SO_2) and particulate matter (PM), aldehydes, chlorinated dioxins (Black *et al*., 2011; Kim *et al*., 2011; Smith, 2000).

Often, PM_{10} is used as an indicator for indoor air pollution in developing countries, but $PM_{2.5}$ has been found to have great impact on the respiratory systems and the body cannot completely remove this toxin form the human body (Sanbata *et al*., 2014). Households using open fires have found to have levels as high as, 3542 $\mu g/m^3$ in Pakistan (Amanat *et al*., 2015), 5000 $\mu g/m^3$ in Guatemalan villages (Neaher and Smith, 2000), above 8000 $\mu g/m^3$ in Nepal (Lahani, 2011). In Zimbabwe a value of 2000 $\mu g/m^3$ was recorded while in Kenya, the levels were between 300 – 15000 $\mu g/m^3$ (Ezzati and Kammen, 2001). With the series of studies carried out in developing countries (Li *et al*., 2016; Ezzati, 2008; Balakrishnan *et al*., 2002), the recorded 24-hour level for $PM_{2.5}$ showed that the expected WHO guidelines of 50 $\mu g/m^3$ for buildings were far from being attained.

With a high percentage (53 percent) of the Nigerian population (estimated at over 145 million people) living in rural areas, the unsustainable use of wood fuel is likely to continue as long as infrastructural investment in clean energy technologies is not put in place. Although the country is estimated to have 80 million cubic metres per year of potential wood fuel reserve (International Food Policy Research Institute, 2010), without the provision of strategies for the sustainable use of this resource, it will result in diminishing supplies of fuel wood.

This study therefore presents results from the measurements of indoor air pollution in Irasa community of Ado Ekiti, Nigeria. $PM_{2.5}$ concentrations measured because of the associated health impact of this particulate matter.

Material and methods

1.1 Study households

The study was carried out at Irasa community, a peri-urban settlement in Ado Ekiti, Nigeria (7^0 40' North and 5^0 16' East) between February and May 2011 (wet season). Temperatures fluctuating between latitude 23' and 40' were measured during the study period.

Householders comprised mostly of farmers, living in a single rooms within the building with narrow alley made of mud bricks and corrugated iron sheets, and with majority of the buildings having eaves. Wood fuels were relied upon for cooking, which were usually gathered freely from nearby forest and farmlands. Usually, householders keep wood stocks especially during wet season as wood fuel cannot be gathered daily. Kitchens were located indoors, in open spaces and using external walls of building (Figure 1). The open space kitchens were located in close proximity to buildings and this allowed smoke to penetrate into buildings and neighbours buildings as well. In selecting buildings for the $PM_{2.5}$ measurements, the type of kitchen location determined participant households' eligibility in the study.

1.2 Data collection

In the study site, measurements of $PM_{2.5}$ concentrations were taken in selected households representing the different housing conditions in the area. Using a structured questionnaires, basic household characteristics information on kitchen types (indoors, open space and exterior wall of the building), primary cooking and lighting fuel type, building materials type, and presence of eaves were collected. The study focused on measuring particulate matter since it is a key indicator of pollutant for health effects of combustion products (Zhou *et al*., 2006).

Households with kitchen types in Figure 1 were considered for the sampling. The convenience sampling method was used in selecting participating households because of their willingness to participate in the study and to further ensure that basic household characteristics were included. On a weekly basis two houses were targeted so that measurements can be made for indoor and outdoor[1] kitchen locations (Figure 1). 18 households in Irasa community were selected for sampling. Prior to householders' recruitment, permission was sought from the community leader. For the participating households, the study protocol was explained to them and they were assured of no health-related side effects of mounting measuring equipment in their buildings.

The University of California, Berkeley (UCB) monitors specifically developed for measuring indoor air pollution in developing countries were used in measuring $PM_{2.5}$ concentrations in buildings. The UCB monitor using photoelectric methods measures particulate matter of a size similar to respirable dust and logs the concentrations each minute (Edwards *et al*., 2006). UCB monitor as shown in Figure 1, were placed in buildings to obtain daily air pollution estimates for a week. The continuous seven-day monitoring was undertaken to capture the average daily 24 h measurement of $PM_{2.5}$ and to determine the consistency in the distribution of air quality levels for all the

[1] For this study outdoor kitchen referred to open space and exterior wall of the building.

days. Two monitors were used during the study to obtain particulate matter levels in buildings. Each monitor measured $PM_{2.5}$ levels within buildings for 9 indoor and 9 outdoor kitchen types (Figure 1).

The monitors were placed 125cm above the floor and 150cm away from the door and windows in measuring $PM_{2.5}$ levels in the buildings. Prior to use, the UCB monitors were calibrated before shipment and pre-tested at Nottingham University's School of Geography laboratory.

The photoelectric chamber of the UCB monitors was cleaned weekly after use with isopropyl alcohol. Ziploc bags were used to zero the monitor before each use, and zeroing of monitors was done 30 minutes before placing them in the buildings. After retrieving the monitors from the buildings after each measurement, they were placed inside the Ziploc bag for post-sampling zeroing for 20 minutes before downloading the data. The time series data measured at 24 h interval was downloaded using the UCB Browser 2.5 software. Regular checks were made in homes to ensure monitors were not tampered with and locations with observed anomalies were recorded.

Microsoft Excel 2010 was used in calculating the average daily and weekly levels of $PM_{2.5}$ from the data uploaded from the UCB monitors, and mass concentrations presented in $\mu g/m^3$.

Figure 1: Kitchen types and $PM_{2.5}$ measurements at Irasa community
A: indoor kitchen; B: external wall building kitchen C: open space kitchen; D: UCB monitor

Results

The 18 households recruited for the study showed that they all used mud and corrugated iron sheets in constructing their buildings. Of the 18 households sampled, 7 each of indoor and outdoor kitchens users had eaves in their buildings. Amongst outdoor kitchen users, 4 used open space and 5 households attached kitchen to the external wall building. The major types of fuel used were wood fuel among 15 households (83%) and the remaining 3 (17%) households used kerosene for cooking. 10 households among the wood fuel users light the wood with kerosene, this generates smoke which disperses within indoor space and wind further forces the smoke back into buildings from outdoor kitchens.

Houses with indoor kitchen at Irasa community usually do not have closing door at the main building entrance and exit (Figure 1: A), while open space kitchen are located at about 5 meters away from the building. Unlike households cooking indoors, buildings with kitchens attached to building external walls have doors. Cooking activities and times take place almost at the same period in the community which usually starts around 5am for breakfast preparation and 6pm for dinner.

In order to better describe daily variability of exposure to indoor air pollution, continuous weekly sampling was carried out in homes. Particulate matter concentrations were analysed using two averaging periods: 24 h average and weekly average.

The summary of $PM_{2.5}$ concentrations for each type of kitchen is presented in Table 1. One household result using outdoor kitchen (HH7) was excluded because the monitor was tampered with midway of measurement. In households that used indoor kitchen, the 24 h mean $PM_{2.5}$ concentrations ranges between 48 $\mu g/m^3$ and 648 $\mu g/m^3$. For households using outdoor kitchens, the observed particulate matter concentration is between 42 $\mu g/m^3$ and 275 $\mu g/m^3$. The results show that there are differences in particulate matter concentration within buildings of the different types of kitchens in the community.

With regards to outdoor kitchens, $PM_{2.5}$ concentration dropped in households using the open space (HH3, HH4, HH8, and HH9), while the particulate matter concentrations remained high in kitchens attached to external building walls and indoor kitchens.

The weekly measured $PM_{2.5}$ in buildings with indoor kitchen was between 62 $\mu g/m^3$ (SD=110) and 229 $\mu g/m^3$ (SD=1234) (Table 2). In households where cooking take place outdoors, $PM_{2.5}$ concentration ranges between 34 $\mu g/m^3$ (SD=231) and 169 $\mu g/m^3$ (SD=526), which is nearly half the concentrations from indoor kitchen. The standard deviations for all the different kitchen locations was high, indicating that on the average there are significant variations in the variables. However, the lower mean values in comparison with standard deviation shows the relatively widespread of the values around their means. Particulate matter levels reached a maximum high of 31575 $\mu g/m^3$ for indoor kitchens and 22602 $\mu g/m^3$ in buildings with outdoor kitchens. In all of the buildings particulate matter concentrations were high regardless of the kitchen type used for cooking activities in the community.

Table 1: Average 24 h $PM_{2.5}$ levels in buildings

24 h daily mean level of $PM_{2.5}$ ($\mu g/m^3$) for buildings with indoor (outdoor) kitchens							
ID	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
HH1	107 (275)	109 (168)	103 (103)	136 (211)	127 (140)	126 (134)	136 (154)
HH2	648 (87)	110 (80)	106 (152)	120 (132)	100 (95)	109 (101)	118 (98)
HH3	73 (78)	77 (60)	96 (61)	104 (65)	77 (66)	133 (101)	NR
HH4	97 (72)	164 (45)	86 (47)	226 (91)	171 (51)	103 (65)	103 (42)
HH5	165 (159)	232 (104)	171 (62)	161 (60)	152 (208)	144 (130)	71 (91)
HH6	133 (188)	185 (129)	100 (104)	114 (110)	140 (111)	139 (119)	111 (95)
HH7*	539	207	53	541	48	149	74
HH8	63 (130)	60 (60)	60 (65)	59 (66)	62 (77)	69 (71)	63 (70)
HH9	132 (189)	83 (88)	60 (88)	61 (81)	70 (66)	62 (75)	68 (94)

HH: household; NR: no recordings; *only indoor $PM_{2,5}$ level presented

Table 2: Weekly levels of $PM_{2.5}$

Average weekly level of $PM_{2.5}$ ($\mu g/m^3$) for buildings with indoor (outdoor) kitchens				
ID	Mean	Maximum	St. dev.	95%
HH1	120 (169)	4841 (22602)	211 (526)	438 (455)
HH2	188 (106)	6125 (7341)	532 (260)	458 (271)
HH3	93 (34)	16255 (3294)	231 (78)	223 (103)
HH4	135 (59)	31575 (2977)	693 (107)	354 (153)
HH5	172 (116)	23612 (6149)	822 (370)	414 (269)
HH6	131 (122)	14633 (10433)	460 (379)	351 (356)
HH7*	229	25603	1234	365
HH8	62 (76)	2861 (10122)	110 (286)	48 (137)
HH9	77 (99)	9211 (11801)	133 (434)	295 (200)

*only indoor $PM_{2,5}$ level presented

Discussions

For the households sampled, wood fuel are mostly used for cooking activities, while a handful used kerosene. The result of the observed average daily and weekly indoor air quality in buildings using different locations for cooking activities at Irasa community indicated that particulate matter ranges between 42 $\mu g/m^3$ and 648 $\mu g/m^3$ (indoor kitchen), and 34 $\mu g/m^3$ and 229 $\mu g/m^3$ (outdoor kitchen) respectively. The reduction in $PM_{2.5}$ concentrations in some homes were associated reduced cooking times during the week measurement because they were away from home. Although, at one location equipment failure was recorded due to removal of the battery, nonetheless, particulate matter concentrations were consistently high in homes.

Findings from this study have shown consistency with other studies that kitchen location, fuel characteristics, building structure, and ventilation are some of the factors contributing to poor ambient quality in homes (Ocheieng *et al.*, 2012; Fullerton *et al.*, 2009) when cooking with biomass fuels. The altering of cooking environment are not sufficient enough to improve on air quality in homes as buildings are closely built to each other. The use of outdoor kitchens and the presence of eaves in buildings partially allowed infiltration of cooking smoke into homes thereby compromising the air quality. The retaining of fire overnight in the hearth in indoor kitchens to avoid lighting cold wood in the morning, further increased particulate matter concentrations in buildings.

The difference in cooking location was not in any way better for buildings air quality when households largely relied on biomass fuels for domestic activities which allows $PM_{2.5}$ concentrations to be high regardless of kitchen location. The cooking smoke generated from cooking locations diffused into the buildings and wafts around, which made the daily average of 25 $\mu g/m^3$ for $PM_{2.5}$ as recommended by WHO (WHO, 2010) to be exceeded for buildings air quality. It shows that air quality failed to meet WHO guidelines and there are wide gaps between guidelines and the real air quality in buildings. $PM_{2.5}$ concentrations were high in the buildings regardless of kitchen location. As households largely relied on biomass fuels for domestic activities both household and neighbourhood air quality would be deteriorating which further echoes Akpalu *et al*.,s study.

Although, particulate matter measurements in peri-urban households are limited Nigeria, studies carried out urban areas of developing countries
The study was carried out during a single dry season which could not account for seasonal effects of fluctuations in the moisture content of wood fuel. Since, the daily temperature and humidity were not constant throughout the year, it is impossible to mitigate for the seasonal effects during this study.

Conclusion

Findings from this study shows that emissions from the different kitchen locations contributed to the high $PM_{2.5}$ in buildings. With continued use of biomass fuels for domestic activities, particulate matter levels would always be high in buildings and further impact on the health of the householders. There is a need to both consider cooking locations and fuel types in order to enhance indoor air quality in buildings. Current study was limited to a number of houses in Irasa community during the dry season. Therefore, the seasonal variations in the study area shows that indoor air pollutions would not be the same all the year round.

Acknowledgement

The funding support received through Nigerian Tertiary Education Fund in carrying out this study at University of Nottingham, United Kingdom is deeply appreciated. The author wishes to thank Prof Georgina Endfield, Dr Sarah Jewitt and Dr Mike Clifford all of University of Nottingham, United Kingdom for the guidance they provided during the period my study in the University. Many thanks to the participating households without whom this study would not have been possible.

References

Akpalu, W., Dasmani, I. and Aglobitse, P. B. 2011. Demand for cooking fuels in a developing country: To what extent do taste and preferences matter? *Energy Policy*, 39, 6525 – 6531.

Amanat, H., Ali, Z., Sidra, S., Nasir, A. and Colbeck, I. 2015. $PM_{2.5}$ arising from different cooking fuels in rural residential houses, *The Journal of Animal and Plant Sciences*, 25(3 supp.2), 677 – 680.

Balakrishnan, K., Parikh, J., Sanker, S., Padmavathi, R., Srividya, K., Venugopal, V., Prasad, S. and Pandey, V. L. 2002. Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of Southern India, *Environmental Health Perspectives*, 110(11), 1069 – 1075.

Black, R. R., Meyer, C. P., Touati, A., Gullett, B. K., Fiedler, H. and Mueller, J. F. 2011. Emissions of PCDD and PCDF from combustion of forest fuels and sugarcane: A comparison between field measurements and simulations in a laboratory burn facility, *Chemsophere*, 83, 1331 – 1338.

Bruce, N., Dora, C., Krzyzanowski, M., Adair-Rohani, H., Wangchuk, T. and Morawska, L. 2013. Tackling the health burden from household air pollution (HAP): Development and implementation of new WHO guidelines, *Air Quality and Climate Change*, 47(1), 32 – 38.

Edwards, R., Smith, K. R., Kirby, B., Allen, T., Litton, C. D. and Hering, S. 2006. An inexpensive dual-chamber particulate monitor: Laboratory characterization, *Journal of Air and Waste Management Association*, 56(6), 789 -799.

Ezzati, M. 2008. Indoor air quality/Developing nations, *International Encyclopaedia of Public Health*, 547 – 553.

Ezzati, M. and Kammen, D. M. 2001. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: An exposure-response study, *Lancet*, 358, 619 – 629.

Fullerton, D. G., Semple, S., Kalambo, F., Suseno, A., Malamba, R., Ayres, J. G. and Gordon, S. B. 2009. Biomass fuel use and indoor air pollution in homes in Malawi, *Occupational and Environmental Medicine*, 66(11), 777 – 783.

International Food Policy Research Institute. 2010. Alternative energy sources for agricultural production and processing in Nigeria, *Policy Note*, 24. Available at http://www.ifpri.org/sites/default/files/publications/nssppn24.pdf (accessed 10/08/2016).

Kim, K-H., Pandey, S. K., Kabir, E., Susaya, J. and Brown, R. J. C. 2011. The modern paradox of unregulated cooking activities and indoor air quality, *Journal of Hazardous Materials*, 195, 1 – 10.

Li, T., Cao, S., Fan, D., Zhang, Y., Wang, B., Zhao, X., Leaderer, B. P., Shen, G., Zhang, Y. and Duan, X. 2016. Househild concentrations and personal exposure to $PM_{2.5}$ among urban residents using different cooking fuels, *Science of The Total Environment*, 548 – 549, 6 – 12.

Lohani, S. P. 2011. Biomass as a source of household energy and indoor air pollution in Nepla, *Iranica Journal of Energy and Environment*, 2(1), 74 – 78.

Neaher, L. P. and Smith, R. 2000. Indoors and outdoor $PM_{2.5}$ and CO in high and low density Guatelan village, *Journal of Exposure Analysis and Environmental Epidemiology*, 10(6), 544 – 551.

OECD/IEA. 2011. *Energy for all: Financing access for the poor*. Available at http://www.worldenergyoutlook.org/media/weowebsite/2011/weo2011_energy_for_all.pdf (accessed 10/08/2016).

Ochieng, C. A., Vardoulakis, S. and Tonne, C. 2012. Are rocket mud stoves associated with lower indoor carbon monoxide and personal exposure in rural Kenya? *Indoor Air*, 23, 14 – 24.

Sanbata, H., Asfaw, A. and Kumie, A. 2014. Indoor air pollution in slum neighbourhoods of Addis Ababa, Ethiopia, *Atmospheric Environment*, 89, 230 – 234.

Smith, K. R. 2000. Environmental Health – for the rich or for all? *Bulletin of the World Health Organisation*, 28(9), 1156 – 1157.

UNDP. 2009. *The energy access situation in developing countries: A review focusing on the least developed and sub-Saharan Africa*. New York: UNDP and WHO.

WHO. 2010. *WHO guideline values for indoor air quality: Selected pollutants*. Europe: WHO.

World Energy Assessment. 2000. *Energy and the challenge of sustainability*. New York: UNDP.

Zhou, Z., Jin, Y., Liu, F., Cheng, Y., Liu, J., Kang, J., He, G., Tang, N., Chen, X., Baris, E. and Ezzati, M. 2006. Community effectiveness of stove and health education interventions for reducing exposure to indoor air pollution from solid fuels in four Chinese provinces, *Environmental Research Letter*, 1, 1 – 12.

Contact email: oluwakemi.akintan@eksu.edu.ng