*American Chemical Science Journal*
*11(3): 1-13, 2016, Article no.ACSJ.22075*
*ISSN: 2249-0205*

**SCIENCEDOMAIN *international***
www.sciencedomain.org

# Comparative Studies of Carbon Monoxide (CO) Exposure in Homes Using Different Cooking Fuels

**Ize-Iyamu Oghomwen Christie[1*], Ukpebor Justina Ebehirieme[2], Ize-Iyamu Osaro Karl[3], Isara Alphonsus Rukevwe[4] and Ukpebor Emmanuel Ehiabhi[5]**

*[1]Rubber Research Institute of Nigeria, Iyanomo, Nigeria.*
*[2]Lancaster Environmental Centre, Lancaster University, LAI 4YQ, UK.*
*[3]Department of Chemistry, Ambrose Alli University, Ekpoma, Nigeria.*
*[4]Department of Community Health, University of Benin Teaching Hospital, Benin City, Nigeria.*
*[5]Department of Chemistry, University of Benin, Benin City, Nigeria.*

***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors IIOC and UEE designed the study and managed the literature searches. Authors IIOC and IIOK carried out the CO, humidity, temperature monitoring and wrote the first draft of the manuscript. Authors IIOC, UJE and UEE wrote the protocol and performed the statistical analysis. Author IAR carried out the health impact assessment and wrote the report. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/ACSJ/2016/22075
*Editor(s):*
(1) Zhonghao Li, School of Materials Science and Engineering, Shandong University, China.
*Reviewers:*
(1) Juliana Jalaludin, Universiti Putra Malaysia, Malaysia.
(2) Yordanka Tasheva, University "Prof. Dr A. Zlatarov –Burgas, Bulgaria.
Complete Peer review History: http://sciencedomain.org/review-history/12546

***Original Research Article***

***Received 16th September 2015***
***Accepted 7th November 2015***
***Published 3rd December 2015***

## ABSTRACT

In-situ atmospheric monitoring of carbon monoxide (CO) was carried out in ten homes where n-butane gas, kerosene stove and firewood were used as cooking fuels respectively. Of the ten houses, four houses surveyed used n-butane gas only as the fuel type, four other houses used kerosene stove only while the last two houses used firewood only. A dosimeter, humidity/ temperature meter were used in determining the concentrations of the CO, the humidity and the temperatures in the selected homes in urban environments. The diurnal trends of carbon monoxide were monitored for about six weeks in these homes. Health Impact Assessment (HIA) was

**Corresponding author: E-mail: christieizeiyamu@gmail.com;*

conducted in these homes using the different cooking fuels after baseline levels of carbon monoxide concentration in the homes were assessed during cooking hours and non–cooking hours. A total of 59 respondents drawn from the ten selected homes were interviewed concerning their experiences of symptoms suggestive of exposure to carbon monoxide. A total of 28 (47.5%) respondents reported had symptoms suggestive of exposure to carbon monoxide. CO levels was highest in the houses were firewood was used as the fuel source and lowest in the houses where n-butane gas was used. However, comparing the results obtained with the World Health Organization and Federal Ministry of Environment standards of 9ppm and 10ppm respectively, the CO values were found to be above limits in some of the houses where n-butane gas, kerosene were used and above the set limits in all the houses where firewood were used as cooking fuel. CO Routine monitoring is recommended and the discontinuous use of firewood as cooking fuel should be strongly enforced not only to reduce the CO concentration but also minimize deforestation.

*Keywords: In-situ; carbon monoxide; dosimeter; diurnal trends; HIA; n-butane gas; kerosene; firewood.*

## ABBREVIATIONS

*H1 to H10 stands for houses number 1 to 10; N= Northing's (longitude); E=Easting's (latitude)*

## 1. INTRODUCTION

Carbon monoxide CO, also known as carbon (II) oxide is an odourless, colourless gas that usually remains undetectable until exposure results in injury or death. Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries [1]. Carbon monoxide is highly toxic. It combines with hemoglobin to produce carboxyhemoglobin, which is ineffective for delivering oxygen to bodily tissues. Concentrations as low as 667 ppm may cause up to 50% of the body's hemoglobin to convert to Carboxy Hemoglobin (COHb) [2]. A level of 50% COHb may result in seizure, coma, and fatality. Short time scales, carbon monoxide absorption is bioaccumulative, since the half-life is about 5 hours in fresh air. CO poisoning is preventable; nonetheless, unintentional, non--fire-related CO poisoning is responsible for approximately 15,000 emergency department visits and nearly 500 deaths annually in the United States [3]. Affected families often believe they are victims of food poisoning. Infants may be irritable and feed poorly. Neurological signs include confusion, disorientation, visual disturbance, syncope and seizures [4].

Carbon monoxide is present in small amounts in the atmosphere as a product of volcanic activity but also from natural and man-made fires (such as forest and bushfires, burning of crop residues, and sugarcane fire-cleaning). The burning of fossil fuels also contributes to carbon monoxide production. Carbon monoxide occurs in dissolved in molten volcanic rock at high pressures in the Earth's mantle [5]. Because natural sources of carbon monoxide are so variable from year to year as the natural contributors such as volcanic eruption do not occur regularly, it is extremely difficult to accurately measure natural emissions of the gas. Man-made sources are more contributors to CO emissions. It is a temporary atmospheric pollutant in some urban areas from the exhaust of internal combustion engines (including vehicles, portable and back-up generators, lawn mowers, power washers, etc.), but also from incomplete combustion of various other fuels (including wood, coal, charcoal, oil, paraffin, propane, natural gas, and trash).

Carbon monoxide (CO) poisoning is a leading cause of unintentional poisoning deaths in the United States [6]. In the United States, the Permissible Exposure Limits (PEL) for CO in workplace atmosphere is between 35- 50 ppm time weighted average (TWA), [7]. Available studies indicate that indoor air pollution (IAP) from household cooking space and space heating apparently causes substantial ill health in developing countries where the majority of the household rely on fossil fuels, biomass and solid fuels(coal), but there are many uncertainties. The uncertainties include life style and habits of the occupants such as smoking, burning of refuse in the neighborhood e.t.c. Carbon monoxide is absorbed through breathing and enters the blood stream through gas exchange in the lungs. Normal circulating levels in the blood are 0% to 3%, and are higher in smokers. Carbon monoxide levels cannot be accessed through a physical exam. Laboratory testing requires a blood sample (arterial or venous) and laboratory analysis on a CO-Oximeter. Additionally, a noninvasive carboxyhemoglobin test method from Pulse CO-Oximetry exists and has been validated compared to invasive methods [8].

Although many people associate public exposure to air pollution primarily with urban outdoor settings, but this study gives awareness that indoor environments can be contaminated both from pollution penetrating from outside and from indoor sources. In closed environments, the concentration of carbon monoxide can easily rise to lethal levels. The American Association of Poison Control Centers (AAPCC) reported 15,769 cases of carbon monoxide poisoning resulting in 39 deaths in 2007. In 2005, the CPSC (U.S consumer product safety commission) reported 94 generator-related carbon monoxide poisoning deaths and forty-seven of these deaths were known to have occurred during power outages due to severe weather, including Hurricane Katrina. Still others die from carbon monoxide produced by non-consumer products, such as cars left running in attached garages.

CO is an indirect greenhouse gas that has the potential to increase the amount of other greenhouse gases (methane), and eventually oxidizes into the main greenhouse gas, $CO_2$, thus contributing indirectly to global climate change and its attendant consequences.

## 2. MATERIALS AND METHODS

### 2.1 Study Area and Home Selection

This study was conducted at some selected homes in Benin City, Edo State. Southern Nigeria. Benin City is an urban city (2006 estimated population of 1,147,188) and the capital of Edo State in Southern Nigeria. It is a city approximately 25 miles north of the Benin River. It is situated 200 miles by road east of Lagos. Benin is the centre of Nigeria's rubber industry, but processing palm nuts for oil is also an important traditional industry [9].

The selection of household for this study was based on voluntary participation.

In the ten household selected, n-butane gas, kerosene or firewood where used exclusively as an energy source for cooking. During each selection visit, questionnaires were administered to the head of each family that was willing to participate. The questions concerned the characteristics of the occupants in the home, type of cooking fuel, family size, cooking duration, and house and kitchen design, e. t. c, which provided information about the daily activity pattern in each home.

### 2.2 CO Determination

Carbon monoxide measurement was carried out using a CO dosimeter, model 627, BK Precision USA. This sampler has a range from 0-1000ppm, with a sensitivity of 1ppm, an accuracy of ±5%, operating temperature from 15 to 90%. [10-12].

Continuous CO measurements were carried out during cooking and non –cooking hours. Sampling time ranges from 5.00 am - 9.00 am in the morning, 1.00 pm - 3.00 pm in the afternoon and 4 pm – 8 pm in the evenings at the respective homes where different fuel types were used for cooking. CO concentrations were determined indoor; kitchen, living room and outdoor. Air temperatures and humidity were measured simultaneously before and after the CO measurements using a humidity/ temperature meter with resolutions of 0.1% RH and 0.1ºC (model RS 1364, RS component Ltd, UK).

The data/results were subjected to statistical evaluation from where the mean and standard deviations were obtained.

## 3. RESULTS AND DISCUSSION

**Air Quality Standards:**

- Federal Ministry of Environment =10.00 ppm
- World Health Organization= 9.00 ppm

Table 1 presents the results obtained from the determination of the concentration of CO in the different houses , during non – cooking and cooking hours respectively where fuel source where n-butane gas, kerosene and firewood respectively in the morning afternoon and evening.

Table 2 below represents the spatial trends of the carbon monoxide emissions from house 1-10 at the different sampling sites; kitchen and living room.

**Air Quality Standards**

- Federal Ministry of Environment =10.00 ppm
- World Health Organization= 9.00 ppm

From houses 1 – 10,during cooking hours, in the kitchen the CO concentrations was lowest in house 1 at 3.00.ppm were n-butane gas was used as the fuel source and highest in house 9 at

16.43 ppm were fire wood was used as the fuel source. House 3 had the highest CO concentration in the living room during cooking hours which was at 6.25.ppm and lowest in house 1,2 and 4 at 1.00.ppm respectively. The concentrations of CO outdoors and indoors during non – cooking hours, could be attributed to non – anthropogenic source; natural sources. CO concentrations indoors recorded during cooking hours is attributed to the emissions from the fuel source during cooking which are affected by meteorological factors such as; temperature and humidity, which were also monitored during this study as seen in the table. Concentrations of carbon monoxide during cooking hours varied in some houses with same cooking fuel. This could be attributed to the kitchen design in each houses, ventilation, source strength ,even the state of the burners, as well as the family size consequently longer cooking hours and hence more CO emissions.

CO concentration in the kitchen during cooking hours were found to be below regulatory limits in houses 1,2,4,6 and 8, at 3.30, 6.10, 4.27, 5.75 and 5.50 ppm respectively, while in houses 3,5,7,9,10 it was found to be above regulatory limits at 12.00, 11.00, 11.20, 16.43 and 14.75. ppm respectively. In the living room, concentration of CO were found to be below the regulatory limits in all the houses under study during cooking hours as shown in bar chart showing mean CO values versus regulatory limits as shown in Fig. 3b.

## 3.1 Health Impact Assessment Report

A total of 59 respondents drawn from ten homes were interviewed concerning their experience of symptoms suggestive of exposure to carbon monoxide. Table 1 show the age and sex distribution of the respondents. A higher proportion of the respondents 16 (27.1%) were less than 10 years. Nineteen (31.3%) were aged 21 to 40 years while only 4 (6.8%) were above 50 years of age. A slightly more than half 32 (54.2%) of the respondents were males.

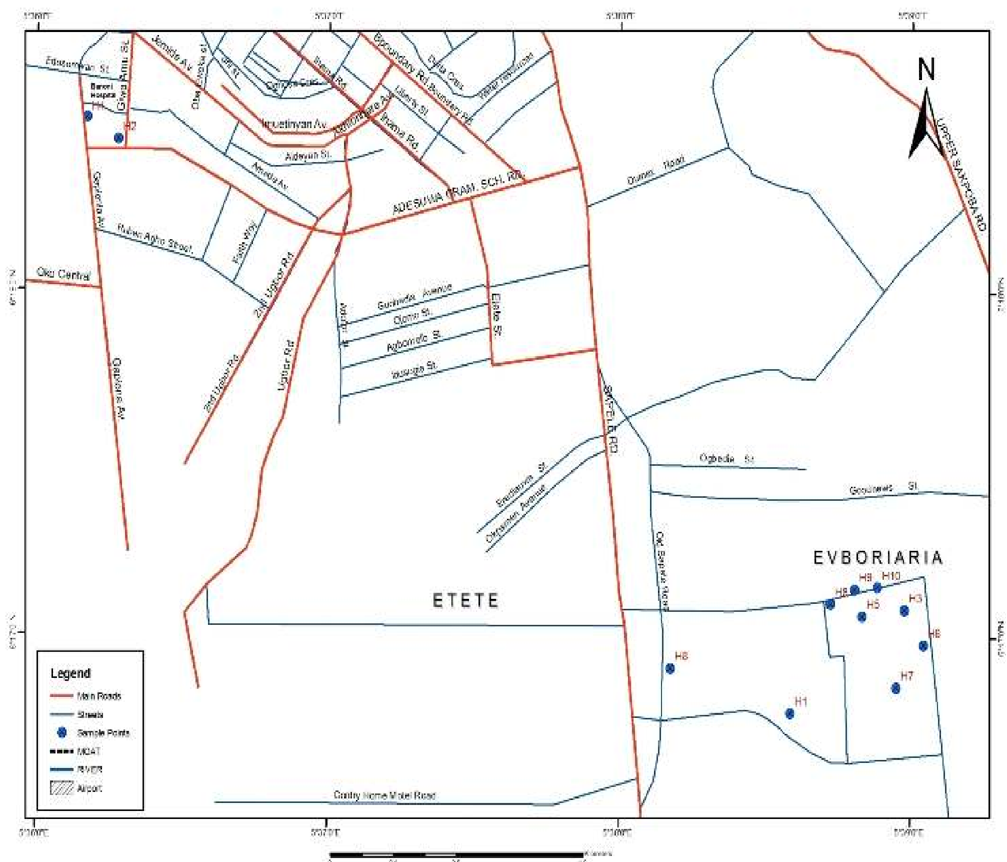


**Fig. 1. Map of Benin City in Edo State, Nigeria with the Coordinates of the Selected Homes**

**Sampling Site A (Kitchen)**

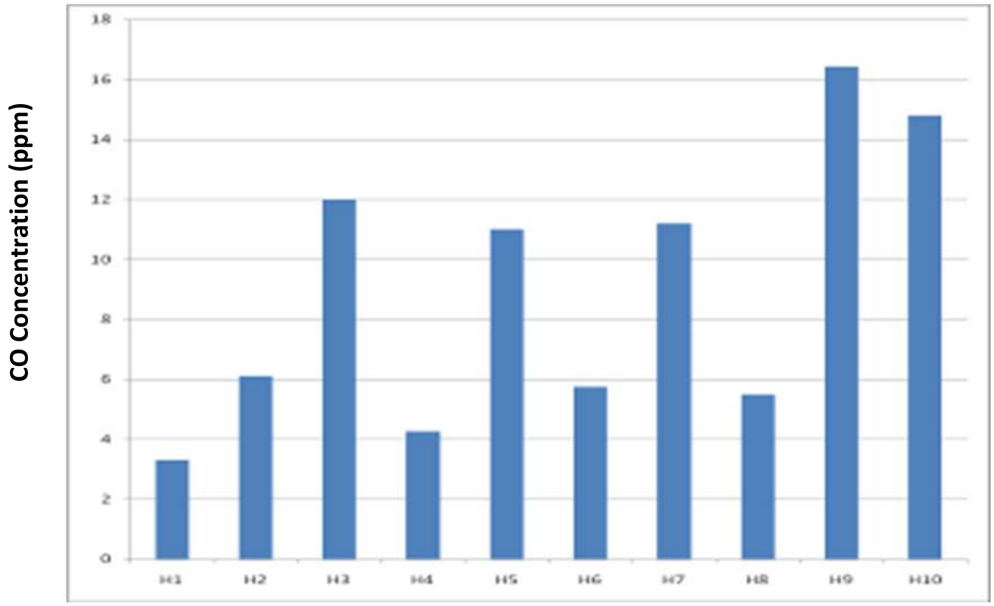


**Fig. 2a**

**Sampling Site B (Living Room)**

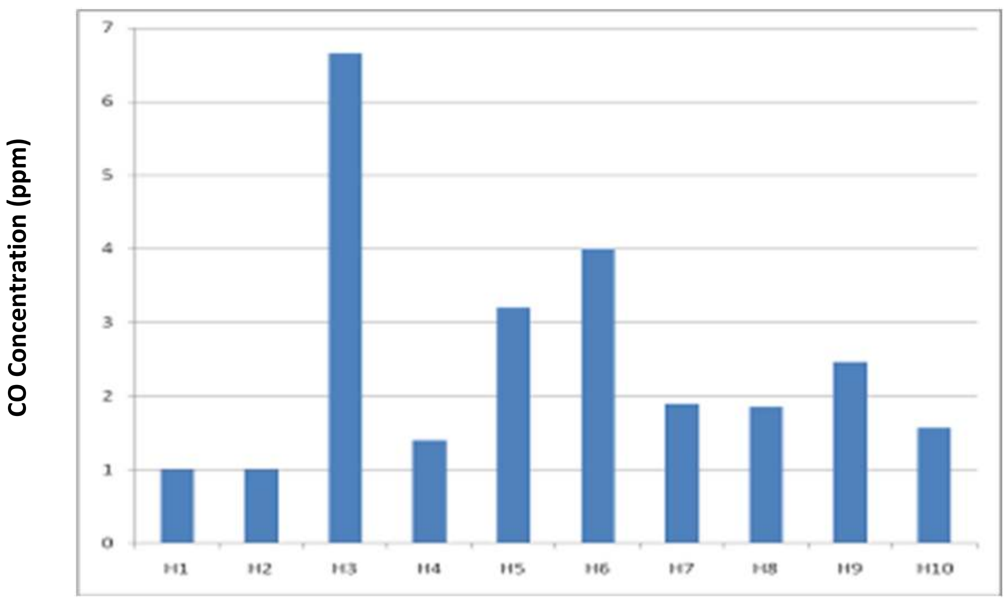


**Fig. 2b**

**Figs. 2a and 2b. Spatial trends of co emissions from the different houses during cooking hours**
**H1-H4 (Fuel type: n-Butane Gas) * H5-H8 (Fuel type: kerosene) *H9 & H10 (Fuel type: firewood); *Outdoor Spatial Trends of CO Emissions in the Different Houses, H1 = 2.00 ppm H3 = 2.00 ppm H5 = 1.83 ppm H7 = 1.17 ppm, H 2 =1.00 ppm H4 = 1.00 ppm H6 = 1.75 ppm H8 = 1.35 ppm, H9 = 1.87 ppm H10 = 2.66 ppm*

A total of 28 (47.5%) respondents reported having had symptoms suggestive of exposure to carbon monoxide. These symptoms of experienced by the respondents are shown in Table 2. Headache was the most common symptom experienced by a higher proportion 12 (20.3%) of the respondents. This was followed by muscle twitches 9 (15.3%), palpitations 6

(10.2%) and dyspnoea when walking upstairs 6 (10.2%). Five (8.5%) respondents experienced dizziness, chest pain and vomiting respectively. Only 2 (3.4%) respondents reported nausea and dyspnoea when walking on level ground. Of the 28 (47.5%) who reported one symptom or another, 12 (42.9%) had relief in their symptoms outside their homes. Three houses surveyed used gas only as the fuel type, 4 houses used kerosene stove only while 2 houses used firewood only. A review of the results from the questionnaire of the inhabitants from the different houses studied revealed that the complains/ health effect recorded was as a result of the type of cooking fuels used in their respective homes.

**Kitchen**

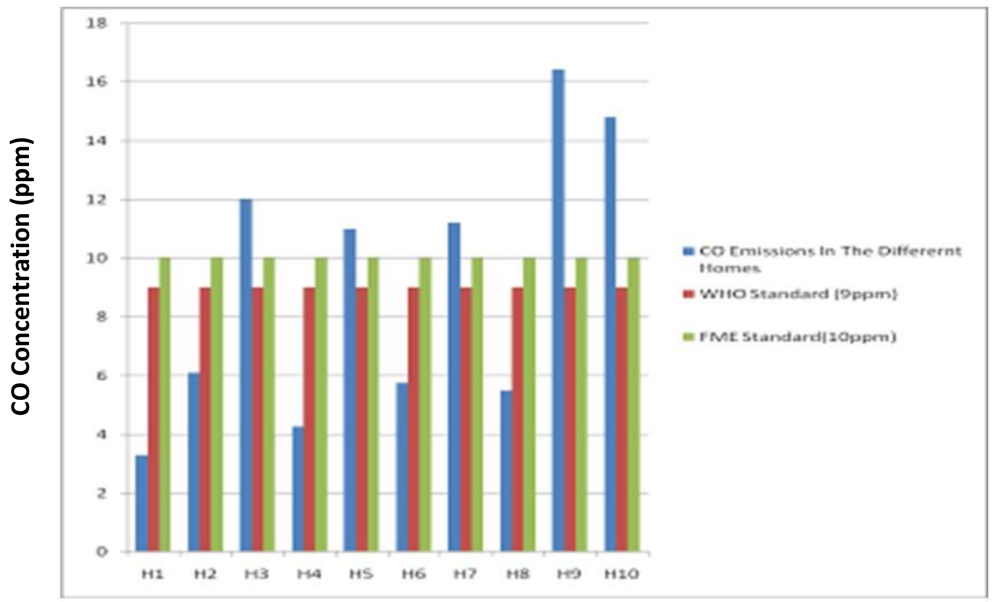


**Fig. 3a**

**Living Room**

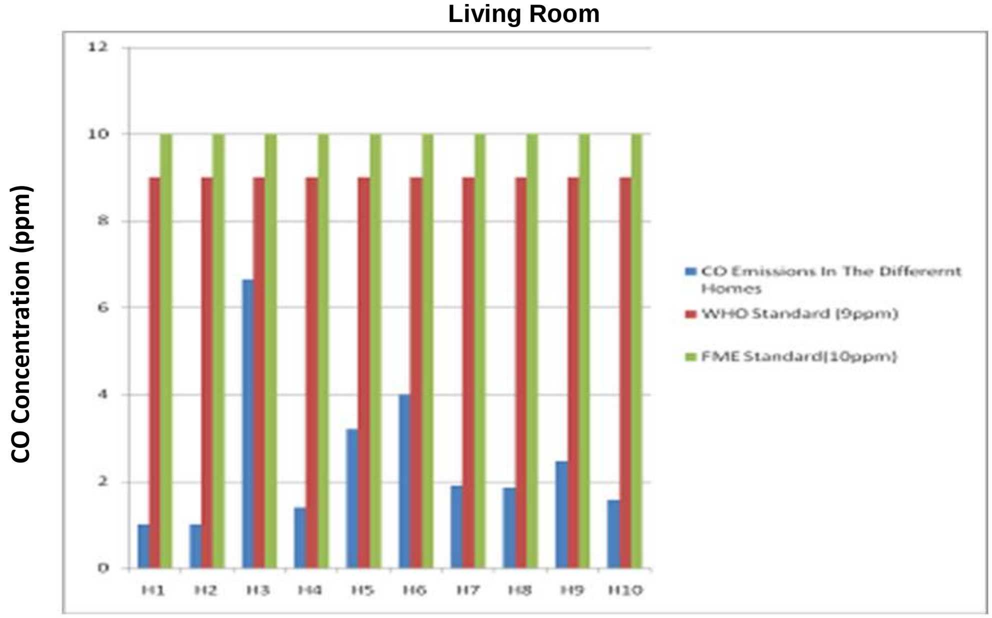


**Fig. 3b**

**Figs. 3a and 3b.Spatial trends of co emissions from the different houses during cooking hours versus regulatory standards**

**Table 1. Mean co values obtained from the different houses using different fuel sources**

| Household description code, fuel type and sampling sites | Non-cooking hours | | | Cooking hours | | |
|---|---|---|---|---|---|---|
| | Morning | Afternoon | Evening | Morning | Afternoon | Evening |
| H1 (n-Butane Gas) | | | | | | |
| Kitchen | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 4.00±0.00 | 3.0 0±0.00 | 3.00±0.00 |
| Living Room | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 2.00±0.00 | 1.00±0.00 |
| H2 (n-Butane Gas) | | | | | | |
| Kitchen | 1.00±0.00 | - | 1.00±0.00 | 6.60±0.39 | - | 5.60±0.14 |
| Living Room | 1.00±0.00 | - | 0.00±0.00 | 1.00±0 .00 | - | 1.00±0.00 |
| H3 (n-Butane Gas) | | | | | | |
| Kitchen | 0.00±0.00 | - | 0.00±0.00 | 15.50±0.14 | - | 8.50±0.07 |
| Living Room | 0.00±0.00 | - | 0.00±0.00 | 8.30±0.02 | - | 4.20±0.04 |
| H4 (n-Butane Gas) | | | | | | |
| Kitchen | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 3.00±0.00 | 3.8 1±0.50 | 6.00±0.10 |
| Living Room | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 |
| H5 (Kerosene) | | | | | | |
| Kitchen | 1.50±0.50 | - | 1.00±0.00 | 11.40±1.60 | - | 10.60±0.03 |
| Living Room | 1.50±0.50 | - | 1.00±0.00 | 2.00±0 .00 | - | 4.40±0.02 |
| H6 (Kerosene) | | | | | | |
| Kitchen | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 7.20±0.20 | - | 4.30±0.04 |
| Living Room | 1.00±0.00 | 1.00±0.00 | 1.00±0.00 | 5.50±0.02 | - | 2.50±0.03 |
| H7 (Kerosene) | | | | | | |
| Kitchen | 1.00±0.00 | 1.80±0.04 | 2.00±0.00 | 11.00±0.03 | - | 11.40±0.46 |
| Living Room | 0.00±0.00 | 1.90±0.03 | 1.70±0.50 | 2.80±0.03 | - | 3.00±0.00 |
| H8 (Kerosene) | | | | | | |
| Kitchen | 0.00±0.00 | - | 0.00±0.00 | 5.60±0.32 | - | 5.40±0.30 |
| Living Room | 0.00±0.00 | - | 0.00±0.00 | 1.70±0.03 | - | 2.00±0.00 |
| H9 (Firewood) | | | | | | |
| Kitchen | 1.50±0.05 | 0.00±0.00 | 1.00±0.00 | 17.81±0.05 | 16.49±0.13 | 15.00±0.11 |
| Living Room | 1.75±0.10 | 0.00±0.00 | 1.00±0.00 | 2.48±0.02 | 2.29±0.01 | 2.60±0.02 |
| H10(Firewood) | | | | | | |
| Kitchen | 1.00±0.00 | 0.00±0.00 | 1.00±0.00 | 15.36±0.42 | 14.42±0.20 | 14.59±0.17 |
| Living Room | 1.00±0.00 | 0.00±0.00 | 1.00±0.00 | 1.00±0.00 | 1.85±0.03 | 1.85±0.02 |

*Values are the mean of six replicates ± SD*

**Table 2. The spatial trends of the carbon monoxide emissions from all the houses**

| Samplig sites | Non – cooking hours | Cooking hours |
|---|---|---|
| **H1** | | |
| Kitchen | 0.00±0.00 | 3.30±0.00 |
| Living room | 0.00±0.00 | 1.00±0.00 |
| **H2** | | |
| Kitchen | 1.00±0.00 | 6.10±0.27 |
| Living room | 0.00±0.00 | 1.00±0.00 |
| **H3** | | |
| Kitchen | 0.00±0.00 | 12.00±0.11 |
| Living room | 0.00±0.00 | 6.25±0.03 |
| **H4** | | |
| Kitchen | 1.00±0.00 | 4.27±0.20 |
| Living room | 1.00±0.00 | 1.00±0.00 |
| **H5** | | |
| Kitchen | 1.25±0.25 | 11.00±0.82 |
| Living room | 1.25±0.25 | 3.20±0.01 |
| **H6** | | |
| Kitchen | 1.00±0.00 | 5.75±0.12 |
| Living room | 1.00±0.00 | 4.00±0.03 |
| **H7** | | |
| Kitchen | 1.60±0.01 | 11.20±0.25 |
| Living room | 1.20±0.03 | 2.75±0.02 |

| Samplig sites | Non – cooking hours | Cooking hours |
|---|---|---|
| **H8** | | |
| Kitchen | 0.00±0.00 | 5.50±0.31 |
| Living room | 0.00±0.00 | 1.85±0.02 |
| **H9** | | |
| Kitchen | 0.83±0.03 | 16.43±0.10 |
| Living room | 0.92±0.05 | 2.47±0.02 |
| **H10** | | |
| Kitchen | 0.67±0.00 | 14.75±0.26 |
| Living room | 0.67±0.00 | 1.57±0.02 |

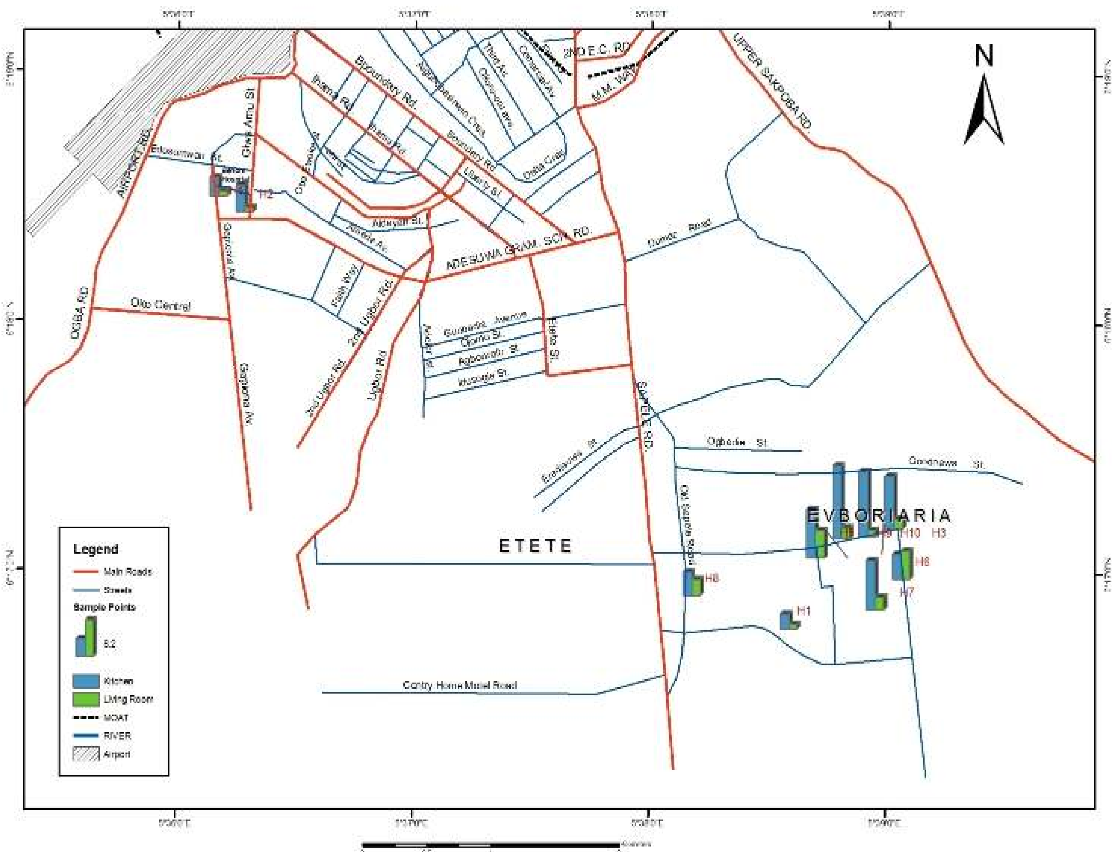


**Fig. 4. Map of Benin city in Edo State, Nigeria showing co concentrations in the houses under study during cooking hours**

## 4. CONCLUSION

There are air quality guidelines in force in order to control and reduce the impacts of air pollution on human health as well as other negative consequences e.g. vegetation damage, climate change, etc. In Nigeria, the national daily threshold for CO is 10.0 ppm (11.4 mgm$^{-3}$) [13]. The WHO regulatory limit for the same pollutant is 9.0 ppm (10.0 mgm$^{-3}$) [14]. The measurement campaign presented herein shows that these limits were clearly exceeded the sampling homes firewood were used as fuel source and few houses where kerosene and n-Butane gas were used respectively. This observation therefore calls for precautionary measures. A recent report concludes that extended exposure to CO can lead to significant loss of life span due to heart damage [15]. As already indicated, Nigeria has one of the lowest average life expectancies (44 years) in the world.

Where the CO levels were found to be lower than the recommended limits, routine monitoring is recommended, to ensure that the CO emissions does not exceed the specified limits to avoid the dangers that could come from CO poisoning. It is also suggested that the continuous use of firewood should be discouraged as the CO emission is quite high. Even in houses were kerosene and n-butane gas is used, proper ventilation, better housing and kitchen design, maintenance and servicing of cooking gas burners should be done regularly, can reduce the concentration of CO in various homes. This suggests that current prevention efforts for CO poisoning, such as home installation of CO alarms, also can apply to the population management of CO on-site. This can be useful in monitoring the impact of such prevention efforts. Additionally, state health departments can partner with local poison centers to obtain additional information from case notes to further characterize populations at-risk, determine the circumstances preceding CO exposure, and help develop local- and state-level approaches to prevent CO exposure.

## CONSENT

All authors declare that written informed consent was obtained from the all parties that voluntarily participated in this study for publication of this case report.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Omaye ST. Metabolic modulation of carbon monoxide toxicity. Toxicology. 2002;180(2):139–150.
2. Tikuisis P, Kane DM, McLellan TM, Buick F, Fairburn SM. Rate of Formation of carboxyhemoglobin in exercising humans exposed to carbon monoxide. Journal of Applied Physiology. 1992;72(4):1311–9.
3. Morbidity and Mortality Weekly Report MMWR. Unit intentional, non--fire-related, carbon monoxide exposures-United States, 2001—2003. 2005;54:36-9.
4. Blumenthal I. Carbon monoxide poisoning. J R Soc Med (The Royal Society of Medicine). 2001;94(6):270–272.
5. Astrid S, Roland K, Sigel O. Metal-carbon bonds in enzymes and cofactors. Royal Society of Chemistry. 2009;243.
6. Morbidity and Mortality Weekly Report. CDC. Carbon monoxide-related deaths-United States, 1999-2004. 2007;56:1309-12.
7. Occupational Safety and Health Adminisstrations OSHA. Carbon Monoxide in Workplace Atmosphere (Direct – Reading Monitor); 2002.
8. Roth D, Herkner H, Schreiber W, Hubmann N, Gamper G, Laggner AN, Havel C. Ann Emerg Med. 2011;58(1)74-9.
9. Benin City. Nigeria, The Columbia Encyclopedia, 6th edition, Columbia University Press; 2005.
10. Wan-Kuen J, Joon-Yeob L. Indoor and outdoor Levels of respirable particulate ($PM_{10}$) and carbon Monoxide (CO) in high rise apartment buildings. Atmos. Environ. 2006;40:6067.
11. Osuntogun B. Quantitative Evaluation of Air Pollutants from Hot-mix Asphalt Facilities in South-West of Nigeria. Intern. J. Chem. 2004;14:71.
12. Ukpebor EE, Ukpebor JE, .Eromomene F, Odiase IJ, Okoro D. Spatail and Diurnal Variations of Carbon Monoxide (CO) Pollution from Motor Vehicles in an Urban Center. Polish J of Environ. Stud. 2009; 19(4):817-832.
13. Federal Environmental Protection Agency FEPA. Guidelines and Standards for Environmental pollution Control in Nigeria; 2002.
14. World Health Organization WHO Guidelines for Air Quality; 2000.
15. Henry CR, Satran D, Lindgren B, Adkinson C. Nicholson CI, Henry TD. Myocardial injury and long-term mortality following moderate to severe CO poisoning. JAMA. 2006;295:398.

## APPENDIX

### Table 3. House hold characteristics

| House location code & fuel type | Family size | No of times cooking is done per day | Cooking durations (mean values) | | | Other household habits e.g. smoking | Coordinates | Elevation |
|---|---|---|---|---|---|---|---|---|
| | | | Morning | Afternoon | Evening | | | |
| HI<br>n-butane gas | 5 | 3 times | 55 mins | 45 mins | 34 mins | None | N 06˚17'00.7''<br>E 005˚38'57.8 | 83 m |
| H2<br>n-butane gas | 22 | 2 times | 38 mins | ---- | 170 mins | None | N 06˚18'22.6''<br>E 005˚36'15.5 | 69 m |
| H3<br>n-butane gas | 6 | 2 times | 79 mins | ---- | 65 mins | None | N 06˚16'57.8''<br>E 005˚36'59 | 72 m |
| H4<br>n-butane gas | 5 | 3 times | 56 mins | 72mins | 73 mins | None | N 06˚18'25.9''<br>E 005˚36'11.8 | 80 m |
| H5<br>Kerosene | 4 | 2 times | 45 mins | ---- | 90 mins | None | N 06˚17'03.5''<br>E 005˚38'56.3'' | 72 m |
| H6<br>Kerosene | 7 | 2 times | 60 mins | ---- | 90 mins | None | N 06˚17'07.1''<br>E 005˚38'59.6'' | 75 m |
| H7<br>Kerosene | 2 | 2 times | 40 mins | ---- | 72 mins | None | N 06˚17'05.3''<br>E 005˚38'57.5'' | 68 m |
| H8<br>Kerosene | 5 | 2 times | 48 mins | ----- | 40 mins | None | N 06˚16'57.5''<br>E 005˚38'07.1'' | 69m |
| H9<br>Firewood | 9 | 3 times | 120 mins | 162 mins | 150 mins | None | N 06˚17'08.2''<br>E 005˚38'46.1'' | 66m |
| H10<br>Firewood | 5 | 3 times | 71mins | 79 mins | 90 mins | None | N 06˚17'08.9''<br>E 005˚38'51.8'' | 75 m |

**Table 4. Age and sex distribution of the respondents**

| Variable | Frequency (n = 59) | Percent |
|---|---|---|
| **Age group (years)** | | |
| Less than 10 | 16 | 27.1 |
| 11 – 20 | 14 | 23.7 |
| 21 – 30 | 10 | 16.9 |
| 31 – 40 | 9 | 15.3 |
| 41 – 50 | 6 | 10.2 |
| Above 50 | 4 | 6.8 |
| **Sex** | | |
| Male | 32 | 54.2 |
| Female | 27 | 45.8 |

**Table 5. Symptoms of exposure to carbon monoxide among the respondents**

| Symptom | Frequency (n = 59) | Percent |
|---|---|---|
| **Headache** | | |
| Yes | 12 | 20.3 |
| No | 47 | 79.3 |
| **Muscle twitches** | | |
| Yes | 9 | 15.3 |
| No | 50 | 84.7 |
| **Palpitation** | | |
| Yes | 6 | 10.2 |
| No | 53 | 89.8 |
| **Dyspnoea when walking up stair case** | | |
| Yes | 6 | 10.2 |
| No | 53 | 89.8 |
| **Dizziness** | | |
| Yes | 5 | 8.5 |
| No | 54 | 91.5 |
| **Chest pain** | | |
| Yes | 5 | 8.5 |
| No | 54 | 91.5 |
| **Vomiting** | | |
| Yes | 5 | 8.5 |
| No | 54 | 91.5 |
| **Nausea** | | |
| Yes | 2 | 3.4 |
| No | 57 | 96.6 |
| **Dyspnoea when walking on level ground** | | |
| Yes | 2 | 3.4 |
| No | 57 | 96.6 |
| **Relief from symptoms outside home*** | | 42.9 |
| Yes | 12 | 57.1 |
| No | 16 | |

**n = 28*

**Table 6. Distribution of respondents according to house number and fuel type**

| House no | Number of respondents | Fuel type |
|---|---|---|
| 1 | 5 | Gas |
| 2 | 5 | Gas |
| 3 | 14 | Gas |
| 4 | 6 | Gas |
| 5 | 5 | Kerosene stove |
| 6 | 4 | Kerosene stove |
| 7 | 6 | Kerosene stove |
| 8 | 2 | Kerosene stove |
| 9 | 5 | Firewood |
| 10 | 7 | Firewood |

**Table 7. Meteorological parameters (mean values)**

| **Sampling site** | | **Non-cooking hours** | | | **Cooking hours** | | |
|---|---|---|---|---|---|---|---|
| | | **Morning** | **Afternoon** | **Evening** | **Morning** | **Afternon** | **Evening** |
| **H1** | | | | | | | |
| Outdoor | TEMP(˚ C) | 27.10±0.06 | 28.60±0.08 | 28.10±0.04 | 26.10±0.19 | 27.70±0.25 | 27.30±0.30 |
| | H % | 96.70±0.50 | 86.70±0.34 | 88.30±0.25 | 99.90±0.00 | 89 .60±0.62 | 92.80±0.50 |
| Living room | TEMP(˚ C) | 27.80±0.55 | 28.10±0.08 | 28.10±0.05 | 27.00±0.00 | 27.30±0.40 | 29.80±0.17 |
| | H % | 94.70±0.40 | 86.10±0.18 | 90.30±0.10 | 99.80±0.40 | 89 .00±0.50 | 85.60±0.40 |
| Kitchen | TEMP(˚ C) | 27.80±0.00 | 28.10±0.05 | 27.80±0.00 | 28.10±0.65 | 28.40±0.62 | 28.20±0.45 |
| | H % | 98.00±0.00 | 86.50±0.08 | 92.10±0.12 | 95.80±0.30 | 75 .70±0.25 | 85.50±0.45 |
| H2 | | | | | | | |
| Outdoor | TEMP(˚ C) | 22.60±0.32 | - | 27.00±0.00 | 22.90±1.00 | - | 25.10±1.63 |
| | H % | 99.90±0.00 | - | 87.00±4.10 | 99.90±0.00 | - | 93.30±1.03 |
| Living room | TEMP(˚ C) | 25.80±0.45 | - | 27.00±0.00 | 27.80±1.46 | - | 26.40±0.52 |
| | H % | 92.20±1.30 | - | 98.00±0.00 | 90.50±0.34 | - | 92.80±0.32 |
| Kitchen | TEMP(˚ C) | 25.90±0.11 | - | 28.80±0.00 | 29.20±1.22 | - | 29.20±1.21 |
| | H % | 88.60±0.77 | - | 90.70±0.15 | 87.70±0.60 | - | 91.90±0.47 |
| H3 | | | | | | | |
| Outdoor | TEMP(˚ C) | 29.70±0.47 | - | 26.80±0.69 | 27.50±0.70 | - | 27.60±0.93 |
| | H % | 99.00±0.00 | - | 99.00±0.00 | 99.30±0.69 | - | 91.90±0.08 |
| L.room | TEMP(˚ C) | 29.80±0.18 | - | 28.20±0.00 | 29.30±0.22 | - | 24.90±0.52 |
| | H % | 87.10±0.92 | - | 87.10±0.92 | 91.20±0.16 | - | 85.50±0.12 |
| Kitchen | TEMP(˚ C) | 29.10±0.48 | - | 29.10±0.48 | 29.90±0.91 | - | 31.20±0.50 |
| | H % | 95.20±0.89 | - | 86.30±0.57 | 89.36±0.57 | - | 85.70±0.16 |
| H4 | | | | | | | |
| Outdoor | TEMP(˚ C) | 27.20±0.44 | 27.30 ± 0.00 | 26.40±0.00 | 25.10±0.74 | 28.60±0.08 | 26.50±0.79 |
| | H % | 91.20±0.17 | 80.50 ± 0.00 | 99.20±0.00 | 99.90±0.00 | 86.70±0.34 | 95.10±0.95 |
| Living room | TEMP(˚ C) | 27.50±0.08 | 28.30 ± 0.00 | 26.00±0.00 | 27.30±0.58 | 26.00±0.00 | 27.90±0.48 |
| | H % | 96.10±0.57 | 86.00 ± 0.00 | 94.00±0.00 | 94.50±0.15 | 83.00±0.00 | 86.90±1.53 |
| Kitchen | TEMP(˚ C) | 27.50±0.08 | 28.30 ± 0.00 | 25.90±0.00 | 27.40±0.59 | 25.30±0.00 | 28.10±0.68 |
| | H % | 96.10±0.13 | 86.00 ±0.00 | 93.00±0.00 | 92.90±0.03 | 84.00±0.00 | 92.00±0.19 |
| H5 | | | | | | | |
| Outdoor | TEMP(˚ C) | 24.30±0.12 | - | 27.40±0.00 | 27.20±0.50 | - | 27.10±0.14 |
| | H % | 99.00±0.00 | - | 99.00±0.00 | 93.30±0.79 | - | 99.20±1.10 |
| Living room | TEMP(˚ C) | 26.40±0.18 | - | 26.90±0.00 | 28.50±0.99 | - | 28.80±0.70 |
| | H % | 96.60±0.41 | - | 97.00±0.00 | 92.80±0.91 | - | 91.30±0.66 |
| Kitchen | TEMP(˚ C) | 26.50±0.50 | - | 26.90±0.00 | 28.30±0.84 | - | 29.70±0.27 |
| | H % | 94.90±0.08 | - | 97.00±0.00 | 94.80±1.30 | - | 87.30±0.90 |
| H6 | | | | | | | |
| Outdoor | TEMP(˚ C) | 24.70±0.15 | 27.00 ± 0.08 | 28.21±0.08 | 25.40 ± 0.39 | - | 26.70±0.68 |
| | H % | 99.90±0.00 | 91.60±0.31 | 95.50±0.71 | 97.00±0.00 | - | 89.90±0.10 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Living room | TEMP(˚ C) | 26.40±0.20 | 26.40±0.20 | 27.90±0.07 | 27.30±0.32 | - | 28.90±0.62 |
| | H % | 99.90±0.00 | 99.90±0.00 | 89.90±0.24 | 99.70±0.43 | - | 93.30±1.09 |
| Kitchen | TEMP(˚ C) | 25.40±0.12 | 28.30±0.05 | 27.70±0.38 | 25.00±0.00 | - | 28.20±0.30 |
| | H % | 99.90±0.00 | 85.80±0.30 | 91.20±0.17 | 79.00±0.00 | - | 89.20±0.03 |
| H7 | | | | | | | |
| Outdoor | TEMP(˚ C) | 23.70±0.12 | - | 28.10±0.05 | 27.20±0.39 | - | 28.40±0.93 |
| | H % | 99.00±0.00 | - | 86.90±0.32 | 93.80±0.30 | - | 92.80±0.57 |
| Living room | TEMP(˚ C) | 26.30±0.09 | - | 28.10±0.06 | 28.30±0.42 | - | 29.10±0.81 |
| | H % | 99.80±0.08 | - | 90.30±0.08 | 90.30±0.38 | - | 88.80±0.90 |
| Kitchen | TEMP(˚ C) | 25.50±0.16 | - | 27.70±0.00 | 28.60±0.90 | - | 30.20±0.75 |
| | H % | 99.90±0.00 | - | 94.50±0.00 | 94.50±1.13 | - | 93.90±0.28 |
| H8 | | | | | | | |
| Outdoor | TEMP(˚ C) | 26.70±0.19 | - | 26.90±0.00 | 23.60±0.64 | - | 25.80±0.66 |
| | H % | 99.90±0.00 | - | 99.90±0.00 | 98.10±0.70 | - | 97.70±0.27 |
| Living room | TEMP(˚ C) | 24.70±0.08 | - | 28.00±0.00 | 26.70±0.49 | - | 28.30±0.69 |
| | H % | 94.00±0.92 | - | 97.20±0.00 | 92.30±1.12 | - | 91.50±0.67 |
| Kitchen | TEMP(˚ C) | 28.30±0.38 | - | 27.80±0.00 | 27.89±0.87 | - | 27.89±0.87 |
| | H % | 94.70±0.00 | - | 97.00±0.00 | 95.10±0.74 | - | 95.10±0.50 |
| H9 | | | | | | | |
| Outdoor | TEMP(˚ C) | 27.00±0.00 | 28.90±0.14 | 27.80±0.00 | 25.10±0.61 | 29.18±0.72 | 27.55±0.40 |
| | H % | 99.00±0.00 | 85.40±0.28 | 98.90±0.00 | 89.00±0.21 | 83.51±1.41 | 87.13±0.66 |
| Living room | TEMP(˚ C) | 27.37±0.54 | 28.30±0.00 | 26.00±0.00 | 27.42±0.55 | 27.96±0.91 | 26.88±0.08 |
| | H % | 90.17±0.37 | 86.40±0.33 | 99.90±0.00 | 96.98±2.51 | 83.17±2.36 | 89.95±3.27 |
| Kitchen | TEMP(˚ C) | 26.00±0.18 | 28.30±0.00 | 27.10±0.00 | 27.72±1.20 | 30.34±0.22 | 29.19±0.19 |
| | H % | 90.50±0.55 | 87.00±0.00 | 98.70±0.00 | 97.97±1.30 | 81.20±1.39 | 86.20±0.57 |
| H10 | | | | | | | |
| Outdoor | TEMP(˚ C) | 27.55±0.26 | 28.80±0.12 | 26.90±0.00 | 25.79±0.68 | 31.09±0.85 | 28.12±0.17 |
| | H % | 99.00±0.00 | 95.40±0.24 | 99.90±0.00 | 91.40±1.96 | 81.13±1.58 | 87.85±0.17 |
| Living room | TEMP(˚ C) | 27.69±0.70 | 29.00±0.00 | 27.80±0.00 | 29.22±0.22 | 29.10±1.11 | 30.07±1.19 |
| | H % | 97.69±0.17 | 85.40±0.36 | 92.00±0.00 | 87.55±0.00 | 82.10±1.84 | 88.28±1.25 |
| Kitchen | TEMP(˚ C) | 28.40±1.71 | 28.00±0.00 | 27.10±0.00 | 29.73±0.00 | 31.84±0.87 | 28.75±0.12 |
| | H % | 98.70±1.29 | 88.00±0.00 | 92.00±0.00 | 91.23±0.00 | 73.58±1.67 | 85.44±1.16 |



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://sciencedomain.org/review-history/12546*