

## **Model Estimates and in-situ Measurements of the Concentrations of some Gaseous Pollutants In some selected Standard Kitchens In Makurdi-Nigeria**

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### **Abstract**

This work assessed and compared the concentrations of some gaseous pollutants in some selected standard kitchens in Makurdi-Nigeria using in-situ measurements and models estimates. Mean concentrations of CO, NO<sub>2</sub> and SO<sub>2</sub> were measured using Crowcon gasman meters in all the selected kitchens. The results obtained show that CO and NO<sub>2</sub> concentrations were observed in all the selected kitchens in concentrations below the permissible limit of 20 ppm and 0.6 ppm respectively set by National Ambient Air Quality Standard and SO<sub>2</sub> was not observed. The mean concentrations for model estimates were found to be slightly higher compared to that of in-situ measurement in all the study kitchens for both pollutants, which is an indication of the strength of the model estimate. Pearson product moment correlation coefficient (r) was also computed to be 0.99 and 0.36 for CO and NO<sub>2</sub> respectively. The correlation is very strong and positive for CO (r = 0.99) and is weak but also positive for NO<sub>2</sub> (r = 0.37). This implies that the model estimates used in this work has 99 % validity estimating indoor concentrations of CO where in-situ measurements are not possible. However, the positive correlation between the in-situ measurements and models estimates indicate that both are positively related.

**Keywords:** Standard kitchen, Gaseous pollutants, Permissible limit, Carbon (II) monoxide, Nitrogen (IV) oxide and Sulfur (IV) oxide.

## Introduction

A standard kitchen is a room in a structure with number of extractors that is used or designed to be used for preparation or cooking of food and contains one or both of the following:

(i) Cooking appliances or rough in facilities including, but not limited to: ovens, convection ovens, stove, microwave ovens or similar appliances, 240 volt electrical outlets or any gas line. (ii) a sink less than eighteen (18) inches in depth with a waste line drain one and a half ( $1\frac{1}{2}$ ) or greater in diameter and a refrigerator exceeding five (5) cubic feet in capacity space opening with an electrical outlet that may reasonably be used for a refrigeration exceeding five (5) cubic feet in capacity (Jennifer *et al.* 2014).

On the other hand, an air exchange rate (AER) depicts a measure of the air volume added to or removed from a space (normally a room or house) per hour divided by the volume of the space.

Gas cooking appliances are used in about half of the roughly 12 million housing units in some developed countries (Jennifer *et al.*, 2014). Gas cooking burners emit air pollutants that can affect residential indoor air quality and increase health risks. Emitted pollutants include nitrogen (IV) oxide ( $\text{NO}_2$ ), carbon (II) oxide (CO), and Sulfur (IV) oxide ( $\text{SO}_2$ ). Increased indoor  $\text{NO}_2$  and CO concentrations from gas cooking appliances have been associated with adverse health effects such as wheezing and decreased respiratory function Jennifer *et al.* (2014). Many studies have examined gas appliance-related concentrations of  $\text{NO}_2$  and CO concentrations in homes (Spengler *et al.*, 1994, Yang *et al.*, 2004, and Fortmann *et al.*, 2001). Measurement-based studies are imperative for understanding the physical properties that govern concentrations and exposures in homes. However, the costs and logistics of large-scale monitoring are barriers to using this method to quantify population-wide impacts.

In developing countries, the problem of indoor air pollution is increasing at an alarming rate. In rural areas of India, the most important indoor air pollutants are combustion products of unprocessed solid biomass fuels used by the poor rural folk for domestic cooking (Aakanksha *et al.*, 2014). Bio fuels undergo incomplete combustion releasing complex mixtures of organic compounds which include CO, contaminants such

as sulfur, and trace metals. A negligible amount of CO is also released during the use of liquid petroleum gas (LPG).

A study conducted by Singer *et al.* (2012) measured the concentrations of gaseous pollutants from Natural Gas Cooking Burners (NGCBs) in Indian kitchens and reported peak concentrations of CO and  $\text{NO}_2$  during cooking that ranged from 30 - 45 ppm and 40 - 150 ppm respectively based on a single cook top. They suggested that the hazards posed by NGCBs could be mitigated substantially through the use of venting range hoods that captured cooking burners' pollutants as well as pollutants generated from cooking activities.

A study conducted by Aakanksha *et al.* (2014) in Lucknow North India to assess air quality in kitchens revealed very high concentration of CO,  $\text{CO}_2$ ,  $\text{NO}_2$ , and  $\text{SO}_2$  in Indian kitchens. They found out that, for all fuel sources, the concentrations of these pollutants were higher than the World Health Standard. They suggested that more stringent bio monitoring studies and use of high efficiency cooking devices to employ to cut down the emissions of toxic gases during combustion of bio fuels in Indian kitchens.

Observations were made by Mullen *et al.* (2012) in Northern California. They measured pollutant levels over 6-days period in the 155 homes. They found that among 155 homes, cooking's were done with gas appliances at least once during sampling; the time-integrated measurements had a fitted  $\text{NO}_2$  of 12ppm and 15ppm in kitchens which exceeded NAAQS.

Another study conducted by Jennifer *et al.* (2014) in Southern California to assess the concentrations of CO and  $\text{SO}_2$  for natural gas cooking burners (NGCBs) observed that the emissions of these pollutants from natural gas burners exceeded ambient air quality standard in the ranges of 55-70 % and 7-8 % respectively in homes during a typical week in winter. They suggested that reducing pollutant exposures from NGCBs should be a public health priority. Their results suggested that regular use of even moderately effective venting range hoods would drastically reduce the percentage of pollutants in homes in which concentrations exceed health-based standards.

A community survey was conducted by Olufemi *et al.* (2011) to assess the pattern and determinants of household sources of energy for

cooking in rural and urban areas in South Western Nigeria. They found out that biomass fuels emit high level of gaseous pollutants and are the major sources of fuel used in the rural kitchens for domestic cooking. Electricity and gas was found to be the major fuel sources in the urban kitchens.

In another study carried out by Olufemi *et al.*, (2017) in Southern Western Nigeria to assessed indoor air quality and risk factors associated with respiratory conditions, they observed that there is increased risk of respiratory symptoms and poor lung function test in women using firewood, agricultural waste and charcoal when compared with those using non biomass fuels. They asserted that concentration of NO<sub>2</sub> was low in all the studied kitchens and other pollutants were above the permissible limit set by World Health Organization (WHO).

Observations were made by Akpofure (2015) in Wary - Nigeria. He assessed indoor air quality in Squatter settlement and found out that measured level of NO<sub>2</sub>, CO and PM in the entire sample household were above regulatory limit of 0.06 ppm, 10 ppm and 250 µ/m<sup>3</sup> respectively, as set by the World Health Organization.

Observations from available literatures show that few works have been carried out to ascertain the level of pollutants in Nigerian kitchens. In addition, none of these works has been found to be carried out in kitchens in Makurdi metropolis, Nigeria. Yet majority of the people in this area depend on biomass fuel source for cooking.

Makurdi is located in the north central region of Nigeria along Benue River and at the north-east of Benue State. It lies between Latitude 7.74° N and Longitude 8.51°E with an elevation of 104m. Majority of the inhabitants of this town are civil servants. The kitchens were randomly selected at location A, B, C, D and E, at each location, a kitchen was selected. Table 1 gives some standard kitchens in Makurdi metropolis. The names of these kitchens are represented with some codes.

## Materials and Methods

### Materials

Materials used in this work were: thermometer (0-110°C), wooden stand (measuring 1.0m tall) with a flat top made of wood measuring 15.0cm x 15.0cm, Crowcon gasman meters AMS9501S (0-200 Version) and stop watch. The choice of these equipment is

necessary because they were designed to assess CO, NO<sub>2</sub> and SO<sub>2</sub> in part per million even in relatively inaccessible areas.

### Method

At a selected kitchen, the gasman monitors for measuring CO, NO<sub>2</sub> and SO<sub>2</sub> were placed on the wooden stand of 1.0 meter tall (which is the average height of standing and sitting human being) which was kept inside the kitchen. The gasman monitors were switched on simultaneously and readings were taken in every 5 minutes for 1 hour per day per study kitchen for six days. The average concentrations of the gaseous pollutants were then computed and recorded. This procedure was repeated in all the kitchens.

The indoor gaseous pollutants from cooking gas burners were measured using gasman monitors and mean concentration of the pollutants obtained using the expression (Eguda, 2006):

$$C_{av} = \frac{\sum C_i}{n} \quad (1)$$

where

$C_{av}$  is the average concentration of pollutants,  $C_i$  is the pollutant concentration and  $n$  is the number of observations. The daily mean concentrations of gaseous pollutant were also computed using equation 1.

However, the estimation of indoor and outdoor pollutants was carried out using models adapted from Singer *et al.* (2012):

$$C_{inLi} = \frac{E(t)}{V} [(k_i + a)t + 1] \quad (2)$$

and

$$C_{inOi} = aC_{outi} [(k_i + a)t + 1] \quad (3)$$

The  $C_{inLi}$  is the indoor pollutant concentrations from indoor sources,  $C_{inOi}$  is the indoor pollutant concentrations from outdoor sources,  $I$  is the pollutant species (CO, NO<sub>2</sub> SO<sub>2</sub>),  $V$  is volume of the kitchen,  $E_i$  is the emission rate,  $k_i$  first-order deposition rate constant,  $a$  is air exchange rate (AER), and  $t$  is time.

Equations 2 and 3 were each solved for  $C_{inLi}$  and  $C_{inOi}$ , respectively, with any of the parameters held constant. Equation 2 presents the solution for the indoor concentration resulting from gas emission from indoor sources, while equation 3 is the solution for indoor concentration originating from outdoor sources. Combining equations 2 and 3 gives the total pollutant

concentrations computed as the summed contributions from the two sources. Thus,

$$C_{in\ i} = C_{in\ I\ i}(t) + C_{in\ O\ i}(t) \tag{4}$$

Because of the closeness of the cooks and the gas cooking burners, the probability of human effects that would exist from gaseous pollutants emissions was computed from the mean concentration values using the relation given by Ediagbonya *et al.* (2013) as:

$$\text{Toxicity potential (TP)} = \frac{\text{Observed mean conc.of the species}}{\text{Permissable limit set by NAAQS}} \tag{5}$$

TP > 1 is harmful to human.

Using the correlation model, the relationship between measured and modeled pollutant concentrations was computed. Hence

the correlation coefficient, r was computed using the expression adopted from Adikwu *et al.* (2013):

$$r = \frac{i \sum C_{mes}C_{est} - \sum C_{mes}C_{est}}{\sqrt{i[\sum C_{mes}^2 - \sum (mes)^2][i \sum C_{est}^2 - \sum (C_{est})^2]}} \tag{6}$$

where i is the number of pairs of data described by the coefficient,  $C_{mes}$  is the measured pollutant

concentrations and  $C_{est}$  is the modeled or estimated pollutant concentrations.

**Table 1:** Some selected standard kitchen

Kitchen codes	Volume	Fuel source	Ventilation	Aver temp.	No of extractors
BH	5852	Gas	Cross	39°C	1 large
TG	5544	Gas	One side opened	40°C	3 small
SF	5742	Gas	Closed	45°C	3 small
GP	5236	Gas	Closed	41°C	2 small
CF	4992	Gas	Closed	39°C	3 small

## Results and Discussion

### Results

The results of the in-situ and modeled mean concentrations of some gaseous pollutants in standard kitchens obtained using equations 2 – 4 are presented in Table 2. On the other hand Table 3 gives the computed Toxicity potential

(TP) for pollutant types in the kitchens, while Table 4 gives the correlation coefficient between monthly measured ( $C_{mes}$ ) and estimated ( $C_{est}$ ) CO and NO<sub>2</sub> concentration in the selected kitchens. In addition, Figure 1 portrays the comparisons of the measured and estimated mean concentrations of the gaseous pollutants in the standard kitchens.

**Table 2:** Measured and estimated mean concentrations of gaseous pollutants in the selected standard kitchens in Makurdi metropolis

Kitchens	Concentrations of gaseous pollutant (ppm)								
	NO <sub>2</sub>			SO <sub>2</sub>			CO		
	$C_{out}$	$C_{mes}$	$C_{est}$	$C_{out}$	$C_{mes}$	$C_{est}$	$C_{out}$	$C_{mes}$	$C_{est}$
BH	0.004	2.040	2.060	0.0010	0.100	1.646	0.000	0.000	0.000
TG	0.008	3.790	3.980	0.0010	0.100	0.993	0.000	0.000	0.000
GP	0.006	2.630	2.800	0.0004	0.100	1.427	0.000	0.000	0.000
SF	0.009	3.640	3.880	0.0001	0.100	1.857	0.000	0.000	0.000
CR	0.009	5.350	5.772	0.0001	0.100	0.211	0.000	0.000	0.000

Note:  $C_{out}$ = measured mean concentration of outdoor gaseous pollutants

$C_{mes}$ = measured mean concentration of indoor gaseous pollutants

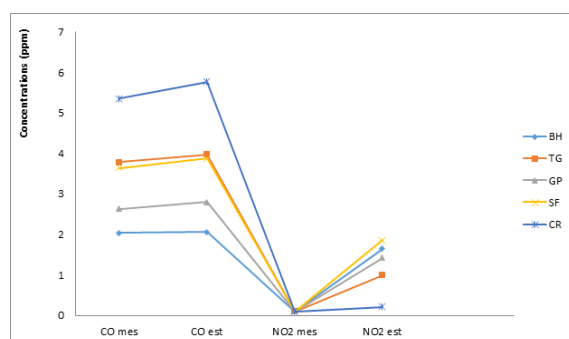
$C_{est}$  = estimated mean concentration of indoor gaseous pollutants

**Table 3:** Toxicity potential (TP) for pollutant types in the kitchens

Kitchen type	Pollutant	TP	Effect
BH	CO	0.102	Not harmful
	NO <sub>2</sub>	0.025	Not harmful
	SO <sub>2</sub>	0.000	Not harmful
TG	CO	0.190	Not harmful
	NO <sub>2</sub>	0.170	Not harmful
	SO <sub>2</sub>	0.000	Not harmful
GP	CO	0.134	Not harmful
	NO <sub>2</sub>	0.170	Not harmful
	SO <sub>2</sub>	0.000	Not harmful
SF	CO	0.182	Not harmful
	NO <sub>2</sub>	0.170	Not harmful
	SO <sub>2</sub>	0.000	Not harmful
CR	CO	0.268	Not harmful
	NO <sub>2</sub>	0.170	Not harmful
	SO <sub>2</sub>	0.000	Not harmful

**Table 4:** The correlation coefficient between monthly measured ( $C_{mes}$ ) and estimated ( $C_{est}$ ) CO and NO<sub>2</sub> concentration in the selected kitchens.

Pollutant	Monthly concentration (ppm)		Correlation coefficient (r)
	$C_{mes}$	$C_{est}$	
CO	17.47	18.49	0.99
NO <sub>2</sub>	05.00	06.14	0.37

**Figure 1:** Comparison of measured and estimated mean concentrations of gaseous pollutants in the standard kitchens.

## Discussion

The result in Table 2 which give the mean measured and estimated concentration of some gaseous pollutants from outside ( $C_{out}$ ) and inside ( $C_{in}$ ) the kitchens indicate a very low concentration of the gaseous pollutants outside the kitchens with the least mean CO concentration of 0.004 and 0.006 ppm obtained outside BH and GP kitchens respectively. On the other hand, the highest mean CO concentration of 0.009 ppm observed each from outside CR and SF kitchens. A careful observation of Table 2 and Figure 1 shows that, model estimation yield slightly higher values of mean CO concentrations as compare to in-situ measurement. This might be as a result of effectiveness of model estimation. A slight positive deviation from  $C_{mes}$  and  $C_{est}$  in Table 2 indicates that both in-situ method and model

estimation are positively correlated. This was contrary to the findings of Jenifer *et al.* (2014) who assessed the concentrations of CO and SO<sub>2</sub> for natural gas cooking burners (NGCBs) in Southern California and observed that the emission of these pollutants from natural gas burners exceeded ambient air quality standard in 55-70 % and 7-8 % in homes during a typical week in winter. However, this discrepancy could as well be due to location and infrastructural differences (REFERENCE).

In addition, the results of Table 2 and Figure 1 comparing  $C_{mes}$  and  $C_{est}$  concentrations of NO<sub>2</sub> showed a wide difference of 0.8 – 0.9 ppm. The results also showed that the highest mean measured and estimated CO concentration of 5.35 and 5.77 ppm respectively obtained in CR kitchen is below NAAQS of 20 ppm. This was contrary to

a study conducted by Singer *et al.* (2012), who measured the concentrations of gaseous pollutants from NGCBs in Indian kitchens and reported peak CO and NO<sub>2</sub> during cooking that ranged from 30-45 and 40 - 150 ppm which is above WHO standard. This could also be due to location differences (REFERENCE).

Table 3 gives the result of T.P. obtained for all the pollutants in the sampled kitchens. It could be observed that the pollutants are not harmful in the kitchens since T.P for the pollutants in all the selected kitchens is less than one. This confirms the fact that the concentrations of these gaseous pollutants are below the NAAQS.

The result in Table 4 gives the correlation coefficient (r) for measured and estimated model for gaseous pollutants. The correlation is very strong for CO with  $r = 0.99$  and is weak for NO<sub>2</sub> with  $r = 0.37$ . This implies that the model used in this work has 99 % validity estimating indoor concentrations of CO where in-situ measurements are not possible.

### Conclusion

The result from this study show that there exists a low concentration of gaseous pollutant (CO and NO<sub>2</sub>) in Makurdi standard kitchens and that SO<sub>2</sub> was not observed in all of the selected kitchens. The findings indicate that the level of pollutant concentrations is not harmful in the kitchens as T.P. for all the pollutant is less than one. The result for both model estimate and in-situ measurement for assessing gaseous pollutant concentrations yields similar results. This study therefore concludes that any of the two methods can be adopted for the assessment of indoor gaseous pollutant.

### Recommendations

This study therefore, recommends more stringent bio monitoring studies and use of high efficiency cooking devices to cut down the emission of gaseous pollutants during combustion of bio fuels in Makurdi kitchens. The study further recommends that awareness should be created to kitchen owners on the need to assess pollutants concentration in their kitchens so that they will allow more researchers and provide factual information of their kitchens.

As a result of financial constraint, this work was confined to Benue State. It is therefore recommend that other scholars wishing to carry a similar research should extend their studies to

other States in Nigeria. It is also recommend that others should carry out the assessment to include other types of pollutant for both kitchens and living rooms.

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### References

- Aakanksha, R.; Katiyar, S. and Rastogi, S.K. (2014). Study of Indoor Air Quality of Kitchens of rural Areas in Lucknow. *Curr World Environ.* 9: 2.
- Adikwu, O; Aduloju, M.O; and Emaikwu S.O. (2013). Measure of Association. *Research Methods and Statistics in Education.* A text book published by Lanrad print, 1:94 - 97.
- Akpofure, R. R. (2015). Assessment of Indoor Air Quality in Selected Households in Squatter Warri Nigeria. *Advance in life science. Journal of scientific and academic publishing.* 5(1): 1-11.
- Ediagbonya, T.F.; Ukpebor, E.; Okiemien, F. and Ogunbowa, G. (2013). Spatio-temporal Distribution of Inhalable and Respirable PM in Rural Atmosphere of Nigeria. *Environmental Skeptics and Critics,* 2 (1): 20-29.
- Eguda, S.O. (2006). Regression and Correlation Analysis. A Text Book on Statistical Methods. Published by Asofad Printing Limited, 2<sup>nd</sup> Edition 9: 75-78.
- Fortmann, R.; Kariher, P. and Clayton, R. (2001). Indoor Air Quality: Residential Cooking Exposures. Final Report. Sacramento, CA: *California Air Resources Board.*
- Jennifer, M.L.; Neil, E.K.; Agnes, B. L, and Brett, C. S. (2014). Pollutant Exposures from Natural Gas Cooking Burners: A Simulation - Based Assessment for Southern California. *Atmos* 26A(11): 2125–2134.
- Mullen, N. A.; Li, J. and Singer, B. C. (2012). Impact of Natural Gas Appliances on Pollutant Levels in California homes. *Lawrence Berkeley National Laboratory (LBNL) 5970e.*
- Olufemi, O.D.; Ololade, O.O.; Ebenezer, K.A.; Tolutope, F.K. and Ayodele, I.O. (2011). A community Survey of the Pattern and Determinants of Household Sources of Energy for Cooking in Rural and Urban

- South Western Nigeria. *The Pan African Medical Journal* 12(2): 2.  
doi:10.11604/pamj.2012.12.2.1436.
- Olufemi, O. D.; Ololade, O.O.; Ebenezer, K. A.; Tolutope, F. K. and Ayodele, I.O. (2017). Indoor Air Quality and Risk Factors Associated with Respiratory Conditions in Nigeria. *African Medical Journal*. 28
- Singer, B.C.; Delp, W.W.; Apte, M.G. and Price, P.N. (2012). Performance of Installed Cooking Exhaust Devices. *Indoor Air* 22:224–234.
- Spengler, J.; Schwab, M.; Ryan, P.B.; Colome, S.; Wilson, A.L.; and Billick, I. (1994). Personal Exposure to Nitrogen dioxide in the Los Angeles Basin. *J Air Waste Manag Assoc* 9– 47.
- Yang, W.; Lee, K. and Chung, M. (2004). Characterization of Indoor Air Quality using Multiple Measurements of NO<sub>2</sub>. *Indoor Air* 14:105–111.