Implications of Different Household Cooking Energy on Indoor Air Quality in Urban and Semi-Urban Settlements in Imo, South Eastern Nigeria

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ABSTRACT: Energy is a basic necessity of life for meeting domestic, social and industrial needs of man. But the use of some of the energy sources has created problems in indoor environment that requires urgent attention. This study assessed the indoor air quality status as regards the effect of different household cooking methods from the use of non-renewable energy sources in parts of Imo State. The cooking methods sampled were firewood stove, kerosene stove, charcoal stove, electricity stove and gas cooker. Indoor air quality was measured by digital air analyzers of different models continuously for 24 hours. Data collected were subjected to ANOVA using the SPSS 12.0 software, and mean values separated with FLSD at P<0.05 as statistically significant. Results showed that CO and PM2.5 concentrations produced during the use of firewood stove in urban settlements recorded the mean (313.94±21.77 and 476.06±203.09 μg/m³), 80 (μg/m³) and 150(μg/m³) NAQS-2006 IAQ. Indoor air qualities from cooking methods in urban and semi-urban are statistically different at (P < 0.05) level. The findings further indicated that gas cooker and electric stove cooking methods have less harmful effects than fuel wood, charcoal and kerosene on the indoor air quality in the study area. This indicated that urban and semi-urban settlements were utilizing energy sources at the lower energy ladder, with fuel wood dominating. Based on the findings, cleaner energy sources should be used in order to reduce indoor air pollution in developing countries.

DOI: https://dx.doi.org/10.4314/jasem.v22i5.23

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Dates: Received: 16 February 2018; Revised: 21 March: 2018; Accepted: 22 April 2018

Keywords: Cooking methods, Indoor air quality, Energy ladder

Worldwide, more than three billion people still burn wood, dung, coal and other traditional fuels inside their homes and the resultant indoor air pollution is responsible for more than 1.5 million deaths a year - mostly of young children and their mothers who spend most of their time at home and in the kitchen (WHO, 2010). A number of scholars such as Mudway et al. (2005), and Saha et al. (2005) inferred that long term exposure to high levels of smoke from burning biomass fuels leads to a host of respiratory diseases. These are significant obstacles towards the achievement of Millennium Development Goals (MDG) 4, 5 and 6 (WHO, 2010). In developing countries, indoor air pollution ranks 8th in terms of risk factors contributing to overall diseases and deaths, 1.1 billion people are exposed to high levels of respirable particles. Over 3 million excess deaths due to indoor air pollution and 300,000 excess deaths due to urban air and rural pollution (Iyiegbuniwe, 2006). In Nigeria for instance, large population live in rural areas and fuel wood is the major source of energy for cooking and lighting (Uwaegbute, 2011), leading to the release of large amount of health damaging pollutants such as particulate matter, SO2, CO2 etc. into the air. Since women are primarily responsible for cooking especially in developing countries and their children often spend time with them while they are engaged in the cooking activities, women and young children are the most affected by indoor air pollutants (Banik, 2010). Based on the Disability Adjusted Life Years (DALYs) approach, which includes both years lived with illness or injury and years of life lost due to premature mortality, household air pollution from solid cook fuels was found to be the largest environmental risk factor and the third greatest risk factor overall for the global burden of disease, with 4.3% of global DALYs (95% confidence interval of 3.4-5.3%) from this source (Lim et al. 2012; Smith et al. 2014; WHO, 2016; Khan et al, 2017). Cooking in a household involve the use of solid fuel and nonsolid fuel (Staton and Harding, 2011; Alphonsus et al, 2014). The use of some solid fuels has been associated with indoor pollution and unsafe levels of toxic emission (Viegi et al, 2004; Staton and Harding,
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2011). Therefore, for an effective prevention and intervention against indoor pollution from household fuel, there is a need to identify the pattern of household cooking fuel for sustainable indoor air quality for man’s survival in urban and rural settings (Owusu and Kuitunen, 2006; Ouedraogo, 2006). This research is to evaluate the impact of different household cooking methods on indoor air quality in the selected parts of Imo State, Nigeria in order to properly inform on household cooking methodology for a healthy and safe indoor air quality.

MATERIALS AND METHODS
Description of the study area: The climate is typical of a tropical humid climate. The mean annual rainfall is between 1990mm to 2238mm, distributed over seven months rainy season period (April to October/November) with bimodal peaks in June and September. The mean daily maximum temperature is between 1990mm to 2238mm, distributed over

September. The mean daily maximum temperature

October/November) with bimodal peaks in June and

seven months rainy season period (April to


The topography is that of Undulated dissected plains with minor hills. In the household, an “ideal” fuel preference ladder with biomass fuels at the bottom and kerosene and electric at the top exists (Leach, 1992). The fuel preference ladder is broken down into 3 categories: biomass fuels, transition fuels, and modern fuels. The biomass fuels are divided into two categories: dung and crop residue, fuel wood which is typical in Nigeria (Plate1). Dung and crop residue reside below fuel wood and are used when fuel wood is scarce. Biomass lies at the bottom of the ladder. On the next tier are transition fuels of charcoal and coal. The top tier consists of kerosene, electric, liquefied petroleum gas (LPG), solar, and wind according to Katie (2012).

Selection of the Study Locations:
Urban Environment: Owerri municipal lies between latitude 05° 15’ E and 05° 30’ N and longitude 07° 00’ E and 07° 15’ W (Wikipedia, 2018).

Semi-Urban Environment: Aboh- Mbaise is located between latitude 5° 27’ N to 70 14’ E and longitude 5° 45’N to 7° 23’ E. The inherent complexity of the semi-urban areas puts the traditional duality of rural and urban areas in question (Juyoung et al, 2015).

Air Quality Sampling Techniques. A combination of monitoring durations and techniques was used to determine the feasibility of multiple methods of assessing the primary cook’s exposure to combustion-related by products (Rupak et al., 2012). Area sampling of CO, NO2, SO2, and PM2.5 occurred continuously for either 24 hours from 20 households randomly selected from urban and semi-urban locations with each having 10 households. Personal sampling of PM2.5 occurred during cooking periods of approximately 2 hours, during which personal continuous CO, NO2, SO2 sampling also occurred. Materials used for the study include the digital air analyzers: NO2 gas monitor, model 1983=range NO- 50ppm = Alarm 1077m, CO2 gas monitor model 1925h Rang = 0.50ppm Alarm = 56PPM and PM 2.5, Pm2 HAZ-TM particulate monitor, Range = 0.1 – 200 µg/m³, Alarm = + 0.0 µg/m³, SO2 gas monitor model 1964H, Range 0.10 99m, Alarm 2.077m air quality monitors. Instruments were handled 1.5 meters above the ground in all locations; in the primary cooking location, the monitor was placed 1 meter from the point in the kitchens for 24 hours. All the measured air qualities were compared with National Air Quality standards, 2006).

Selection of the Study Locations: The climate is typical of a tropical humid climate. The mean annual rainfall is between 1990mm to 2238mm, distributed over seven months rainy season period (April to October/November) with bimodal peaks in June and September. The mean daily maximum temperature averages 27°C all through the year, highest from February to April, with average relative humidity reaching 75% or above, particularly in the rainy season. The to...
Firewood stove produced the highest amount of CO (313.94±21.77), NO$_2$ (19.10±4.91), and particulate matter (476.06±203.09), while charcoal stove recorded the highest SO$_2$ (313.94±17.14) of all the cooking methods. The there was no significant differences in CO produced by Firewood stove, kerosene stove and Charcoal stove; the CO produced by the trio was significantly higher than that produced by electric stove and gas cooker. The gas cooking method produced least of all four pollutants (CO$_2$, SO$_2$, NO$_2$ and PM$_{2.5}$) with values of 46.70±5.41, 149.22±36.96, 9.58±1.83, 10.48±1.44 respectively, which was significantly less than the amounts produced by Firewood stove for all four pollutants, Kerosene stove for CO$_2$ and SO$_2$, Charcoal stove for CO, SO$_2$ and PM$_{2.5}$; and Electric stove for CO and SO$_2$ respectively (Table 1). There was significant difference in the amount of the various indoor air quality (IAQ) from the different cooking methods in the semi-urban environment. Fire wood stove cooking method recorded the highest levels of all the pollutants including CO (320.48±25.03), SO$_2$ (366.50±46.17), NO$_2$ (21.64±3.06) , and PM$_{2.5}$ (562.38±174.87). The least values were recorded in the gas cooker method with values of 50.84±3.48, 37.52±7.27, 10.76±1.21, and 10.48±1.44 respectively. Of the four pollutants, only with regards to particulate matter was the amount produced by firewood stove recorded (562.38±174.87) significantly different from that produced by Charcoal stove (319.66±100.2) (Table 2). From Table 3, the findings indicated that pollutants from different cooking methods in urban and semi-urban environment were statistically different in their individual rows. The result indicate that the gas cooker and electric Stove cooking methods are more environmentally friendly cooking methods (Fig. 1).

The overall mean indoor air pollutants (IAP) in urban environment were in order of viz: SO$_2$≥CO≥PM$_{10}$≥NO$_2$ (Table 1).

### Table 2: The Statistical Summary and description of Cooking Methods on Indoor Air Quality in Semi-Urban environment

<table>
<thead>
<tr>
<th>Cooking Methods</th>
<th>CO</th>
<th>SO$_2$</th>
<th>NO$_2$</th>
<th>PM$_{2.5}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire wood stove</td>
<td>320.48±25.03</td>
<td>366.50±46.17</td>
<td>21.64±3.06</td>
<td>562.38±174.87</td>
</tr>
<tr>
<td>Kerosene Stove</td>
<td>289.44±43.18</td>
<td>308.98±53.71</td>
<td>15.50±2.60</td>
<td>21.62±12.30</td>
</tr>
<tr>
<td>Charcoal Stove</td>
<td>312.12±16.37</td>
<td>343.58±51.59</td>
<td>17.02±3.20</td>
<td>319.66±100.27</td>
</tr>
<tr>
<td>Electric Stove</td>
<td>82.54±8.10</td>
<td>61.02±22.00</td>
<td>11.62±1.67</td>
<td>12.72±2.62</td>
</tr>
<tr>
<td>Gas Cooker</td>
<td>50.84±3.48</td>
<td>37.52±7.27</td>
<td>10.76±1.21</td>
<td>10.48±1.44</td>
</tr>
</tbody>
</table>

*a,b,c,d,e* Means ±SE with different superscripts in the same column are significantly different (P< 0.05)

### Table 3. Comparative assessment of effect of the Cooking Methods on IAQ in the Urban and Semi-urban environment

<table>
<thead>
<tr>
<th>POLLUTANTS ENVIRONMENT</th>
<th>URBAN (µg/m$^3$)</th>
<th>SEMI-URBAN (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>159.00±1.00</td>
<td>168.00±1.00</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>190.00±1.00</td>
<td>174.00±1.00</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>113.00±1.00</td>
<td>145.00±1.00</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>2.75±0.01</td>
<td>25.00±1.00</td>
</tr>
</tbody>
</table>

*a,b,c,d* Means ±SE with different superscripts in the same row are significantly different (P< 0.05)
The Electric stove cooking method followed the Gas cooker method with respect to producing the least amounts of all the pollutants (Fig. 2). The overall mean indoor air Pollutants from the semi-urban environment were in order of: SO$_2$ ≥ CO ≥ PM$_{10}$ ≥ NO$_2$ (Table 2). The result agreed with the report that firewood produced high amount of indoor pollutants and so is a major risk factor for Acute Respiratory Infections (AR) (WHO, 2007; Fullerton et al., 2008). From the comparative studies made, firewood, kerosene and charcoal stove emitted CO above the NAQS-2006, all the cooking methods emitted SO$_2$ above the standard, while firewood and charcoal emitted PM$_{2.5}$ above the standard in urban environment sampled.

The study focused on the effect of different cooking methods on indoor air quality in part of Imo State. The results showed that in urban settlement, gas cooking produced least of all four pollutants, which was significantly less than the amounts produced by Firewood stove for all the four pollutants; Kerosene stove: CO$_2$ and SO$_2$, Charcoal stove: CO, SO$_2$ and PM$_{2.5}$; and Electric stove for CO and SO$_2$ respectively. In semi urban settlement, the results also indicated that, firewood stove recorded the highest levels of all the pollutants. The lowest values were recorded in the gas cooker. The result agreed with Goldenberg (2000) who reported that the use of firewood as source of heating and energy for cooking and lighting causes indoor air pollution and exposes families to air pollution levels as much as 50 times greater than World Health Organization guidelines for clean air, setting the stage for heart and lung disease. Of the four pollutants measured, only with regards to particulate matter was the amount produced by firewood stove recorded significantly different from that produced in Charcoal stove. Accordingly, the overall mean indoor air Pollutants from the urban and semi-urban environments were in order of SO$_2$ ≥ CO ≥ PM$_{2.5}$ ≥ NO$_2$ respectively. The results further indicated in urban and semi-urban locations, except electric stove and gas cooker, firewood, kerosene and charcoal stoves recorded CO above the National Air Quality Standard (NAQS-2006), the four cooking methods had SO$_2$ emission above the NAQS, except electric and gas cooker in semi-urban with NO$_2$ below the standard respectively. Particulate matter was emitted above the NAQS-2006 in firewood and charcoal stoves, while kerosene, electric stove and gas cooker emitted PM$_{2.5}$ below the NAQS-2006 respectively. In semi-urban settlement, firewood, kerosene and charcoal stoves emitted CO and SO$_2$ above the standard, with firewood and charcoal releasing PM$_{2.5}$ above the standard respectively. Carboxy-hemoglobin (COHb) from CO impairs the oxygen-carrying capacity of the blood, putting a strain on tissues with high oxygen demand, such as the heart and the brain (WHO, 1999, Varon et al., 1999). Studies on coal mining resulted to the emission of PM$_{2.5}$, CO, NOx and SOx that caused dizziness, headache, fatigue, and impaired judgment, lung irritation, bronchitis, pneumonia, asthma, respiratory infections, pulmonary edema and emphysema (Ghose and Majee, 2002; Sinha and Sreekesh, 2002; Suman et al., 2007). They also influence the functioning of brain and heart (Ubuoh and Ogbuji, 2016). From the results, SO$_2$, CO and PM$_{2.5}$ are mainly from using traditional cooking methods that are unclean at the lower energy ladder, leading to respiratory problems for women, children, elderly and degradation of the physical environment. The results further showed that indoor air quality from different cooking methods in urban and semi-urban environment were statistically different at (P < 0.05) level of significant. The result is consistent with the findings of Cheong et al (2005), Selvaraj et al., (2014) who observed that household air pollutants from cooking activities are common in developing countries.

Conclusion: From the overall results of the study, households have access to using traditional cooking methods that are environmentally unfriendly energy sources at the lower energy ladder with fuel wood being the highest. It is now suggested that, households should be encouraged to use cleaner burning energy to reduce indoor air pollution in urban and semi-urban environment. Uses of fuel wood for domestic energy needs should be discouraged in order to protect the nation’s forest resources with a view to reduce global warming and menace of soil erosion.

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Ubuoh EA.; Ogbuji S. (2016): Analysis of the Implications of Different Household Cooking…...


