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# Health Implications of Air Quality Index of Fine and Coarse Particulates During Outdoor Combustion of Biomass in the Niger Delta, Nigeria

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## Abstract

Rural dwellers in the Niger Delta commonly use biomass for cooking and other activities. This study investigated the air quality index of fine particulate matter 2.5 (PM2.5) and coarse particulate matter 10 (PM10) and its health implications during outdoor combustion of fuelwood in the Niger Delta, Nigeria. A mini-volume air sampler (model: AEROCET 531) was used to measure PM2.5, PM10, and total suspended particulate (TSP) in the study area. A bimonthly triplicate sampling was carried out at 3 distances in 4 different states spanning one Calendar year. The results showed that PM2.5, PM10, and TSP ranged from 19.85 – 27.95µg/m3, 55.66 – 80.59µg/m3, and 74.29 – 140.44µg/m3, respectively. There was statistical variation across the different months, locations and distances, and their interactions. The concentration of PM2.5 and PM10 occasionally exceeds the World Health Organization limits of 25µg/m3 and 50µg/m3 for 24-hourly average, respectively. The air quality index showed no contamination to slight contamination in both seasons. The air quality index indicates that the air is slightly contaminated at the emission source which decreased as distance away increased. Therefore, there is a need for the regulatory agencies to consider PM2.5 and PM10 in the monitoring of ambient air quality to forestall potential hazards associated with human exposure.

**Keywords:** Aerosols; Biomass combustion; Environmental health; Pollutant; Respirable particulates.

## 1. Introduction

Atmospheric pollution has become a significant challenge in many parts of the world (Tian *et al.*, 2014). Due to increased industrialization, urbanization and population growth in different parts of the world, the adverse effect associated with atmospheric pollution in the environment and its associated biota including humans is on an increasing trend. It is a known fact that pollutants exacerbates the risk of respiratory and cardiovascular systems especially in immune-compromised individuals (Seiyaboh and Izah, 2019).

Some of the major air pollutants include particulates, ozone, ammonia, ammonia, and oxides of sulphur, nitrogen and carbon. Other common air contaminants include heavy metals (Uzoekwe *et al.*, 2021), bioaerosols especially microbial contaminants (Izah *et al.*, 2021) and hydrocarbon from petroleum derivatives. Apart from air, these pollutants also contaminate food materials of human and other environmental components such as soil, water and sediment.

Substances such as dust, particulates and noxious gases are frequently observed in the ambient environment due to anthropogenic activities and seasonal influence. Serious air pollution has occurred in many cities in the world leading to a decline in outdoor air quality (Wan *et al.*, 2016). Environmental health risks resulting from air pollution is a frontline consideration with 90% of people breathing polluted air (Wambebe and Duan, 2020). Particulates in air are among the contaminants of serious concern to humans, and it has been classified as a carcinogenic agent by International Agency for Research on Cancer (Wang *et al.*, 2018). According to WHO (2018), particulates affect people more than other contaminants and the major constituents are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. The reports also showed that particulate matter is made up of organic and inorganic substances.

Particulate matter is basically divided into two; the fine particulate (PM2.5) and coarse particulates PM10 and are characterized by aerodynamic diameter of 2.5µm and 10µm respectively (Ngele and Onwu, 2015). PM2.5 originates from both natural and anthropogenic sources (Bandpi *et al.*, 2020) and is mainly comprised of organic matter, elemental carbon, ion species, and trace elements (Park *et al.*, 2018). PM10 is also inhalable (Tian *et al.*, 2014) and it has multiple sources which include natural dust, industrial emissions and traffic gasses (Liu *et al.*, 2004)

Air quality index of particulates are assessed to ascertain the level of hazard posed to the health of people that dwelled in an area (Cheng *et al.*, 2007; Edokpa and Ede, 2019; Monteiro *et al.*, 2016). Authors have applied several indices in determining the health risk of air pollutants (Edokpa and Ede, 2019; Kanee *et al.*, 2020; Kianisadr *et al.*, 2018; Richard *et al.*, 2019a; Tiwari, 2015). Among the different indices that have been applied in the study of air pollutants, the US Oak Ridge National Laboratory is commonly used due to ability to rank overall air quality of different locations of different pollutant parameters (Kanee *et al.*, 2020). To this effect several studies have been carried in the Niger Delta especially in Port Harcourt (Edokpa and Ede, 2019; Kanee *et al.*, 2020).

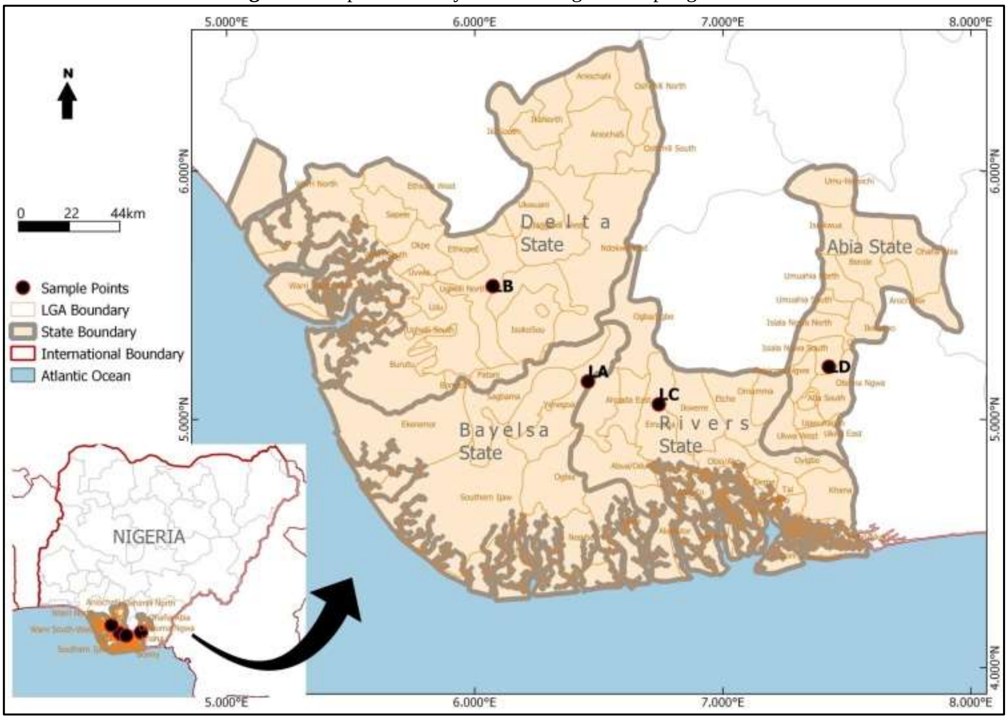
Health risk information on exposure to outdoor biomass combustion during cooking in the area is scanty in literature; hence this study focuses on the health implications of air quality index of $PM_{2.5}$ and $PM_{10}$ during outdoor wood combustion in the Niger Delta region of Nigeria.

# 2. Materials and Methods

## 2.1. Study Area

This study was carried out in four states in the Niger Delta including Delta, Bayelsa, Rivers and Abia (Figure 1). A significant number of persons in the area reside in the rural area where wood fuel (biomass) is the main source of cooking energy. Some of them use it indoor while several others use it in an outdoor setting. The biomass comes from several sources depending on the type of vegetation cover found in the vicinity. In the wet season, the moisture content of the biomass tends to be high. Also the area is characterized by two distinct season viz: wet (April to October) and dry season (November to March). Temperature, wind speed, wind direction and relative humidity of the area have been documented in literature (Richard *et al.*, 2019a; Richard *et al.*, 2019b).

**Figure-1.** Map of the study area showing the sampling locations




## 2.2. Sample Collection

Sampling was carried out in 4 locations viz A (Delta State), B (Bayelsa state), C (Rivers State) and D (Abia state). The study was carried out bimonthly from November 2016 to September 2017 spanning 1 Calendar year cutting across 3 months of wet (May, July and September) and dry (November, January and March) seasons. A total of 216 triplicate samples were collected from 3 distances in a windward direction at 10ft, 25ft and 50ft from the emission source (ie. 3 x 3 = 9 sample) x 4 locations x 6 months.

## 2.3. Sample Measurement

Respire-able particulate matter particularly ($PM_{2.5}$, $PM_{10}$ and TSP) was measured using a mini-volume air sampler (model: AEROCET 531, Manufactured by Met-one instrument, USA). The air sampler has pre-weighed membrane filter (45µm) used to collect particulate matter. It also has pump which moves at a flow rate of 5 LPM at ambient conditions. Separation of the particle size was achieved using an impactor of 10-micron (Ohimain *et al.*, 2013; Richard *et al.*, 2019a). The sensitive analytical microbalance used for weighing has a quartz filter of 47mm diameter (Ohimain *et al.*, 2013; Richard *et al.*, 2019a).

## 2.4. Air Quality Index

Several air quality indexes have been developed by researchers/environmental agencies; there is no universally accepted method, appropriate for all situations (Monteiro *et al.*, 2016). Hence in this study, air quality index developed by US Oak Ridge National Laboratory previously described by Tiwari (2015) applied by Edokpa and Ede (2019) and Kanee *et al.* (2020) was applied. According to Edokpa and Ede (2019) and Kanee *et al.* (2020) the advantage of this index is the ability to rank overall air quality of different locations with different pollutant parameters. This is a non-linear index with exponential function and a coefficient (which may be a constant or may vary) with other non-linear relationship (Edokpa and Ede, 2019). The authors further reported that the relationship contain one or more variable with exponential function.

Air quality index = $[5.7 \sum I]^{1.37}$

Where I is the ratio of the observed concentration of the pollutant to the pollutant standard at National hourly value of 70µg/m$^3$ and 30 µg/m$^3$ for $PM_{10}$ and $PM_{2.5}$, respectively (Edokpa and Ede, 2019; Kanee *et al.*, 2020). The resultant values were categorized as: 00 <AQI≤25 (Clean air), 25 <AQI≤50 (slight contamination), 50 <AQI≤75 (moderate contamination), 75 <AQI≤100 (heavy contamination), and AQI>100 (severe contamination) (Edokpa and Ede, 2019)

## 2.5. Statistical Analysis

Analysis of field data on the ambient of $PM_{10}$, $PM_{2.5}$ and TSP was carried out using SPSS software version 20. A three-way analysis of variance was carried out at p = 0.05 and Duncan statistics was used for mean separation of interactions between months and locations, months and distances, distances and locations.

# 3. Results

The particulate distribution from outdoor combustion of biomass during cooking in some Niger Delta states taken bimonthly, spatio-temporal and at varying distances are presented in Tables 1, 2 and 3, respectively. The concentration of $PM_{2.5,}$ $PM_{10}$ and TSP arising from biomass combustion in the various months of study ranged from 22.03 – 26.34 µg/m$^3$, 61.43 – 96.03 µg/m$^3$ and 96.21 – 124.62 µg/m$^3$, There was significant variations at $p<0.05$ among the various months studied (Table 1). Based on spatio-temporal distribution, $PM_{2.5}$, $PM_{10}$ and TSP ranged from 22.74 – 25.56 µg/m$^3$, 73.34 – 83.10 µg/m$^3$ and 100.64 – 110.57 µg/m$^3$, being significantly different at $p<0.05$ among the locations (Table 2). $PM_{2.5}$, $PM_{10}$ and TSP concentration showed a significant decline at $p<0.05$ as distances away from the emission source increased with a value range of 19.85 – 27.95 µg/m$^3$, 55.66 – 104.49 µg/m$^3$ and 74.29 – 140.48 µg/m$^3$, respectively (Table 3). Interactions of $PM_{2.5}$, $PM_{10}$ and TSP on distances and months, months and locations, locations and distance, and months, distances and locations showed significant differences at $p<0.05$.

**Table-1.** Bimonthly distribution of $PM_{2.5}$ and $PM_{10}$ in outdoor biomass combustion during cooking in the Niger Delta region of Nigeria

| Parameters | Months | | | | | |
|---|---|---|---|---|---|---|
| | November | January | March | May | July | September |
| PM 2.5, µg/m$^3$ | 22.03a | 24.23b | 26.34c | 24.34b | 22.24a | 24.39b |
| PM 10, µg/m$^3$ | 61.43a | 69.34b | 85.01d | 96.03e | 76.63c | 77.25c |
| TSP, µg/m$^3$ | 97.65a | 97.86a | 124.62c | 113.69b | 96.21a | 98.34a |

Means (n=36) with Different letters across the row indicate significant difference at $p<0.05$ according to Duncan multiple range test statistics

**Table-2.** Spatial distribution of $PM_{2.5}$ and $PM_{10}$ in outdoor biomass combustion during cooking in the Niger Delta region of Nigeria

| Parameters | Locations | | | |
|---|---|---|---|---|
| | A | B | C | D |
| PM 2.5, µg/m$^3$ | 22.74a | 23.54b | 23.89b | 25.56c |
| PM 10, µg/m$^3$ | 73.34a | 80.59b | 83.10c | 73.43a |
| TSP, µg/m$^3$ | 103.73a | 103.97a | 110.57b | 100.64a |

Means (n=54) with Different letters across the row indicate significant difference at $p<0.05$ according to Duncan multiple range test statistics

**Table-3.** Distance distribution of $PM_{2.5}$ and $PM_{10}$ in outdoor biomass combustion during cooking in the Niger Delta region of Nigeria

| Parameters | Distance, feet | | |
|---|---|---|---|
| | 10 | 25 | 50 |
| PM 2.5, µg/m$^3$ | 27.95c | 23.99b | 19.85a |
| PM 10, µg/m$^3$ | 104.49c | 72.69b | 55.66a |
| TSP, µg/m$^3$ | 140.48c | 99.42b | 74.29a |

Means (72) with Different letters across the row indicate significant difference at $p<0.05$ according to Duncan multiple range test statistics

The air quality index of $PM_{2.5}$ and $PM_{10}$ during outdoor biomass combustion in the Niger Delta, Nigeria is shown in Table 4. The results of air quality in the area for wet and dry season indicate no contamination i.e. clean air to slight contamination across the different locations and distances. At the emission source i.e. 10ft distances in all the location, the air quality index were slightly contaminated across both seasons. Also in Location B and D in wet season and Location C and D in dry season also showed slight contamination at 25 ft distance, while the rest Locations at 25ft and 50ft distances showed no contamination. The ratio of $PM_{2.5}$ and $PM_{10}$ in wet and dry season ranged from 0.20 – 0.39 and 0.28 – 0.42, respectively.

**Table-4.** Air quality index of $PM_{2.5}$ and $PM_{10}$ during outdoor biomass combustion in the Niger Delta, Nigeria

| **Locations** | **Distances, Feet** | **Air quality index (AQI)** | | | | **$PM_{2.5}$ and $PM_{10}$ ratio** | |
|---|---|---|---|---|---|---|---|
| | | **Wet** | | **Dry** | | | |
| | | **AQI** | **Air description** | **AQI** | **Air description** | **Wet** | **Dry** |
| Location A | 10 | 31.69 | Slight contamination | 33.50 | Slight contamination | 0.26 | 0.30 |
| Location B | 10 | 43.28 | Slight contamination | 36.17 | Slight contamination | 0.20 | 0.30 |
| Location C | 10 | 36.36 | Slight contamination | 40.68 | Slight contamination | 0.22 | 0.28 |
| Location D | 10 | 35.84 | Slight contamination | 34.91 | Slight contamination | 0.31 | 0.30 |
| Location A | 25 | 23.96 | Clean air | 20.01 | Clean air | 0.29 | 0.40 |
| Location B | 25 | 28.26 | Slight contamination | 21.98 | Clean air | 0.28 | 0.36 |
| Location C | 25 | 25.73 | Clean air | 27.91 | Slight contamination | 0.27 | 0.31 |
| Location D | 25 | 26.34 | Slight contamination | 26.04 | Slight contamination | 0.39 | 0.37 |
| Location A | 50 | 23.88 | Clean air | 14.69 | Clean air | 0.28 | 0.42 |
| Location B | 50 | 18.74 | Clean air | 15.34 | Clean air | 0.32 | 0.41 |
| Location C | 50 | 21.97 | Clean air | 15.80 | Clean air | 0.31 | 0.41 |
| Location D | 50 | 18.57 | Clean air | 16.92 | Clean air | 0.39 | 0.37 |

00 <AQI≤25 (clean air), 26 <AQI≤50 (slight contamination), 51 <AQI≤75 (moderate contamination), 76 <AQI≤100 (heavy contamination), and AQI>100 (severe contamination)

## 4. Discussion

The TSP recorded in this study was lower than the daily hourly average of 250 $\mu g/m^3$ recommended by Federal Environmental Protection Agency Nigeria (1991). Also, the concentration of $PM_{2.5}$ and $PM_{10}$ in the study area occasionally exceeds the WHO limit of 25 $\mu g/m^3$ and 50 $\mu g/m^3$ for 24-hourly average, and 10$\mu g/m^3$ and 20 $\mu g/m^3$ annual average respectively. The study found that there were significant variations among the various months, distances and locations and their interactions, an indication of spatio-temporal and seasonal influence in the distribution of particulate in the area. The variation in locations suggests impact of human activities that is contributing to particulates in the area. The study further shows a decline in particulate concentration as distance from source increased.

The trend of this study is in accordance with previous reports on waste dumpsite (Richard *et al.*, 2019a), smallholder gari processing (Richard, 2021) and palm oil processing (Ohimain *et al.*, 2013; Ohimain and Izah, 2013). The values recorded had some similarity with the values recorded in particulates from waste dump (Richard *et al.*, 2019a), smallholder gari processing (Richard, 2021). Wambebe and Duan (2020) reported $PM_{2.5}$ and $PM_{10}$ concentration in the range of 15.30 – 70.20 $\mu g/m^3$ and 16.30 – 77.50 $\mu g/m^3$, respectively in different locations in Abuja metropolis, Nigeria. Kanee *et al.* (2020), studied $PM_{2.5}$ and $PM_{10}$ in Abuja and reported concentration of 15.00 – 95.00 $\mu g/m^3$ and 12.00 – 80.00 $\mu g/m^3$, respectively for dry season, and 9.00 – 75.00 $\mu g/m^3$ and 7.00 – 65.00 $\mu g/m^3$, respectively for wet season. Ngele and Onwu (2015) studied particulates in some urban centres (Onitsha, Aba, Umuahia, Owerri, Enugu, Nsukka, Abakaliki, Afikpo, Orlu and Nnewi) in Nigeria and reported $PM_{10}$ in the range of 55.81 - 921.34$\mu g/m^3$ in dry season and 14.38 - 266.06 $\mu g/m^3$ in wet season, respectively, and $PM_{2.5}$ in the range of 21.69 - 122.88 $\mu g/m^3$ in dry season and 3.31- 11.44 $\mu g/m^3$ in wet seasons, respectively. Jelili *et al.* (2020) reported outdoor $PM_{2.5}$ and $PM_{10}$ in the range of 26.50 – 60.50 $\mu g/m^3$ and 96.80 - 382.70 $\mu g/m^3$ in Ogbomoso, Nigeria. High concentration of $PM_{10}$ could lead to severe health challenges. For instance, an increase in ambient particulate matter ($PM_{10}$) load of 10 $mg/m_3$ reduces life expectancy by 0.64 years (Kanee *et al.*, 2020). Wambebe and Duan (2020), reported $PM_{2.5}$ in Africa showed that only in few instances do the value fall within the interim target 2 range of 25–35 $\mu g/m^3$, and many times the values exceeds 35$\mu g/m^3$. According to the authors, Nigeria is the 3rd largest country in Africa that is exposed to high concentration of $PM_{2.5} \leq 73$ $\mu g/m^3$ on annual basis.

The air quality index of the study area suggests slight contamination at the emission source at the emission source based on the national hourly exposure for both fine ($PM_{2.5}$) and coarse ($PM_{10}$) particulates. There was apparent difference in the air quality index between the study locations, distances and seasons. The air quality index values decrease as distances form the emission sources increases. Also, the air quality index was higher in the wet seasons as compared to dry season. This trend have been reported in both fine ($PM_{2.5}$) and coarse ($PM_{10}$) air quality index in some location in Abuja by Kanee *et al.* (2020). This may be associated to the moisture content of the biomass (wood) being combusted, which may have caused more intense emission from the wood in wet season. Previous findings shows that air quality index ranging from clear to severe contamination in different locations in Port Harcourt (Rumubiakani, Trans Amadi, Woji, Choba, Diobu-Mile, Oyibo and Eleme) Nigeria (Edokpa and Ede, 2019) had some similarity with the findings of this study, but far from the findings of clear air recorded in 10 different locations in Abuja (Kanee *et al.*, 2020). The findings of this study indicate that morbidity and mortality to residents due to air pollution may occur over prolong period. Also the risk ratio of $PM_{2.5}$/ $PM_{10}$ calculated in the study were lower than the allowable standard of 0.5 – 0.8 specified by World Health Organization (Kanee *et al.*, 2020). Jelili *et al.* (2020), also reported ratio $PM_{2.5}/PM_{10}$ as 0.24 which is comparable to the findings of this study. Low $PM_{2.5}/PM_{10}$ ratio suggest that $PM_{10}$ dominated the particulates in the study area. This indicates that adverse effect to sensitive people especially the immune-compromised persons in the area may occur over prolong exposure.

## 5. Conclusion

Particulates are a common air pollutant of public health concern. This is because it can emanate from both organic and inorganic compounds with major compositions being sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. This study evaluated the health implication of particulates due to outdoor exposure to wood fuel (biomass) combustion in the Niger Delta. The study found that the concentration of TSP is within the allowable limit by Federal Environmental Protection Agency, Nigeria, while the $PM_{2.5}$ and $PM_{10}$ often exceeded the limit for 24-hourly average. Also there were significant variations in the concentration of the various particulates across the locations, distances and months as well as their interactions. This indicates spatial differences, or variation in the human activities leading to emission of particulates in the study area. The air quality index indicates that the air showed no contamination to slight contamination, with a decline in value as distances away from the emission sources increased. The $PM_{2.5}/PM_{10}$ ratio suggests $PM_{10}$ dominates the particulates composition of the area. However, there is a need to incorporate this two major particulate in routine monitoring of ambient air quality in different emission sources to forestall adverse health effect over a prolong exposure.

## Authors Contributions

The lead author conceived the ideal, carried out the field data gathering and statistical analysis, while the second and third authors introduced the air quality index and wrote the initial draft. All authors approved the final manuscript.

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