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# Spatial analysis of ambient air quality in the sawmill environment of Ondo Road, ile-ife, Osun state, Nigeria.

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## Abstract

Increasing sawmill industries demand proactive measures in combating ambient air quality in the environment. This research aimed at spatially an alyse ambient air quality in the sawmill environment of Ondo Road, Ile – Ife, Osun state. The study uses Geographic Information System (GIS) to evaluate the particulate matters within buffered zones of sawmill sites in the study area. Both primary and secondary data were used for this research. Primary data employed GNSS observation on existing sawmills and air sample points in the study area. Google Earth Imagery and Base map of the study area were downloaded from Google Earth Pro and Open Street Map respectively for the purpose of secondary data. The research maintained high level of accuracy through instruments check, quality of data acquired and calibrating of device engaged for air monitoring. ArcGIS 10.7.1 and QGIS 3.12 were used for all the geo processing steps. Air sample points were randomly determined within the created buffered zones of below 100m, 101-200m and 201-300m for the selected sawmill sites in the study area. Study discovered the effects of fine particulate matters of 0.3µm remarkably higher in concentration in all buffered zones of different sawmill sites in the study area. Findings established that fine particulate matters of 0.3µm and 0.5µm were the major particles affecting the ambient air quality in the study area and of high health category. While study discovered that coarse particles conformed to established standards with low health category. The result obtained justified geographical variability of ambient air quality in different zones of sawmill sites in the study area with "decreasing linear pattern". Study recommends formation of community engagement committee for the proper orientation of members of public on how to enhance and protects themselves from the emission of sawmills and stakeholders in environmental agencies should be alive to their responsibilities by majorly engaging in aggressive control of preventing fine particles from becoming airborne in the study area.

***Keywords:*** *GIS, ambient air quality, particulate matters, buffered zones, sawmills, established standards.*

## Introduction

Clean fresh air is indispensable ingredient for a good life quality while individual poses the right towards expecting that the breathed air will not harm people within the environment (Olalekan *et al*, 2021). Sawmills are important and indispensable components of the wood supply chain because they connect the conversion flow of raw materials into finished product (Makkonen, 2018). This led to the growing demand of this wood – based product in recent years and as a result, industries constantly looking for ways to increase the quantity of their products. This therefore degenerated into establishing the industries wherever the land is available without due consideration to environmental regulations. This therefore poses a threat to the environment in term of air pollution level that is against established standards. Olalekan *et al* (2021) posited that right to enjoy benefits of clean air is limited by the activities of sawmill industries as well as several glitches that its pollution can cause on public well-being.

The increasing development of human activities has given rise to a significant increase in atmospheric pollutants which may have impact on human health (Atash, 2007). In the cities of developing countries, the environmental problems are much greater, because of the overwhelming scale and speed of urbanization (Atash, 2007). Ambient air pollution has become a major problem in most towns and cities in Nigeria (Pat-Mbano & Nkwocha, 2012). The problem of air pollution is a serious threat to environmental health in many cities of the world (Wong *et al* 2008, Kan *et al* 2009). Studies of urban air quality have shown that human health is negatively impacted by many types of gases and particles that result from the chemical reactions of exhaust gases with the atmosphere (Taesiko *et al*, 2009, Pat-Mbano & Nkwocha 2012). One of the greatest environment risks to health is air pollution (WHO 2021). Therefore, by reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer and both chronic and acute respiratory diseases including asthma. The lower levels of air pollution, the better the cardiovascular and respiratory health of the population will be, both long and short term (WHO, 2021). The greatest air pollution problem in the Nigerian environment is atmospheric dust arising from many industrial processes including sawmill industries (Farombi, 2008). No wonder it was asserted that 4.2 million individuals die prematurely from ambient (outdoor) air pollution yearly in both cities and rural areas of the world (WHO 2021). This risk is higher for city dwellers, especially around the sawmill in developing countries like Nigeria. In spite of the negative impacts associated with sawmill industries, they still provide support for socio-economic living of residents within the communities (World Bank, 2006, Okunomo & Achoja 2010, Olawuni & Okunola, 2014a, Akinbode & Olujimi, 2014, Fagbenro & Abdulahi, 2018).

The concentration of sawmill industries within the environment and its greater air pollution problems has motivated various studies such as Pat-mbano & Nwokocha (2012), Olawuni & Okunola (2014b), Oluwatosin *et al* (2014), Aletan *et al* (2020), Olalekan *et al* (2021) to focus on environmental effects of sawmill industries. Despite the above studies there is still dearth of information on the spatial characteristics and pattern of ambient air quality in the sawmill environment. Therefore, this study poise to explore geospatial techniques in analyzing ambient air quality in sawmill environment of Ondo Road, Ile – Ife, Osun state with a view to provide mitigation measures. This is with specific objectives which were to determine air concentrations and examine the quality levels at varying locations in relation to established standards on the environment of the study area.

## LITERATURE REVIEW

Different works related to the theme of this study are considered in this section. In the study carried out by Olawuni & Okunola (2014) which assessed environmental effects of sawmills activities on residents living at varying distances from sawmills in Ile – Ife, Osun State. The study established that there was a significant difference between distance of residences from sawmills and severity of smoke. Nimyel & Namadi (2019) determined air quality of selected parameters in Zaria and its environs, Kaduna state. The results indicated that the concentration of gaseous pollutants in the study area do not pose any major threat to the environment and human. The study suggested continuous check for those pollutants especially CO that was found higher than the standard. Similarly the study of Mansouri *et al* (2011) investigated monthly variations of ozone layer ($O_3$), sulphurdioxide ($SO_2$), carbonmonoxide (CO) and particulate matter ($PM_{10}$) and their trend in Shiraz city, Iran. This study concluded that there were significant differences in the concentrations of air pollutant parameters at different months. In a related study Pat-Mbano & Nkwocha (2012) investigated impact of sawmill industry on ambient air quality at Utu community in Akwa-Ibom state, Nigeria. Study found that the overall assessment of air quality in this area indicated unhealthful result that means the general health of workers in sawmills and the local population is endangered by emission from sawmill. On the impact of sawmill industry on ambient air quality in Ilorin metropolis, kwara state, Nigeria Raimi *et al* (2020) indicated that as $PM_{10}$ in sawmill environment increases $PM_{2.5}$ increases significantly. In order to mitigate these effects, institution of policies planning to reduce pollution that can be caused by future development was recommended. Likewise the study of Olalekan *et al* (2021) on ambient air quality at major sawmill sites in Ilorin showed that air pollution in the city of Ilorin was found increasingly polluted and are of major health concern because of their synergistic action which can lead to remarkable rise in hospital visits. Study revealed that CO, O2, $PM_{2.5}$ and $PM_{10}$ were below the recommended FMEV standard while VOC, $PM_{2.5}$ and $PM_{10}$ were above WHO standards. Study therefore recommended an enhanced monitoring and modeling of air quality at sawmills. In a related development Ugonabo *et al* (2023) in their study of identification of the spatial patterns of air pollution and its sources in Ogui New Layout, South-East of Nigeria observed that during the dry season, the air pollutants ($PM_{10}$, CO, $SO_2$, and $NO_2$) had maximum values of 225, 10.72, 1.74, 1.93 respectively and minimum values of 184, 8.86, 0.82, and 0.45 respectively. During the wet season, $PM_{10}$, CO, $SO_2$, and $NO_2$ had maximum values of 202, 16.66, 1.65, 0.73 respectively and minimum values of 108, 11.85, 0.69 and 0.26 respectively. It was advised that the local people of Ogui New Layout reduce their exposure to the outdoors especially during the dry season.

Evidence from above showed that major studies were focused on pollution parameters like CO, $NO_2$, $SO_2$ while there are scanty works on the effects of particulate matters in the sawmill environments. The few available ones were mostly concentrated on $PM_{10}$ and $PM_{2.5}$ with little or no efforts on other sizes especially particles of less than $PM_{2.5}$ that are regarded as having greater harm on the environment due to their smaller diameters. The size of particulate matter has been directly linked to its potential in causing health problems (Tao *et al*, 2018). It is against this backdrop that this study attempted to spatially examine coarse and fine particulate matters of different diameters in the context of buffering operation.

## Materials And Methods

### The Study Area

The study area is sawmill environment of Ondo Road in Ile – Ife an ancient Yoruba city, situated in the eastern part of Osun state which lies in the southwestern part of Nigeria. Its geographical location is between Latitudes 7º 24'N and 7º 28'N of the Equator and Longitudes 4º 33'E and 4º 34'E of the Greenwich Meridian. The main city of Ile–Ife spans into two local government areas: Ife East with it headquarter at Oke–Ogbo and Ife Central at Ajebamidele area with its extension in part of Ife North Local Government. The city has an estimated population of 509,082 with the density of 280/km$^2$ (Population census, 2006) and it covers approximately 1,791km$^2$.

The topography of the site has an average gradient slope of less than 0.03 to 5 percent. Soil texture is laterite type with cohesive particles that can support easy flow to run off water. It experiences two major seasons namely, the long raining season with high humidity from mid-March to October and a dry season with harmattan and low humidity from November to early March. It has average rainfall of 1,000 to 1,250mm usually from March to October and a mean relative humidity of 75% to 100%. The temperature is relatively constant throughout the year at an average of 25ºC and with its peak in December – March. The city has a large expanse of forest reserve with thriving timber business and consequently, there are many sawmill industries (Faremi *et al*, 2014).

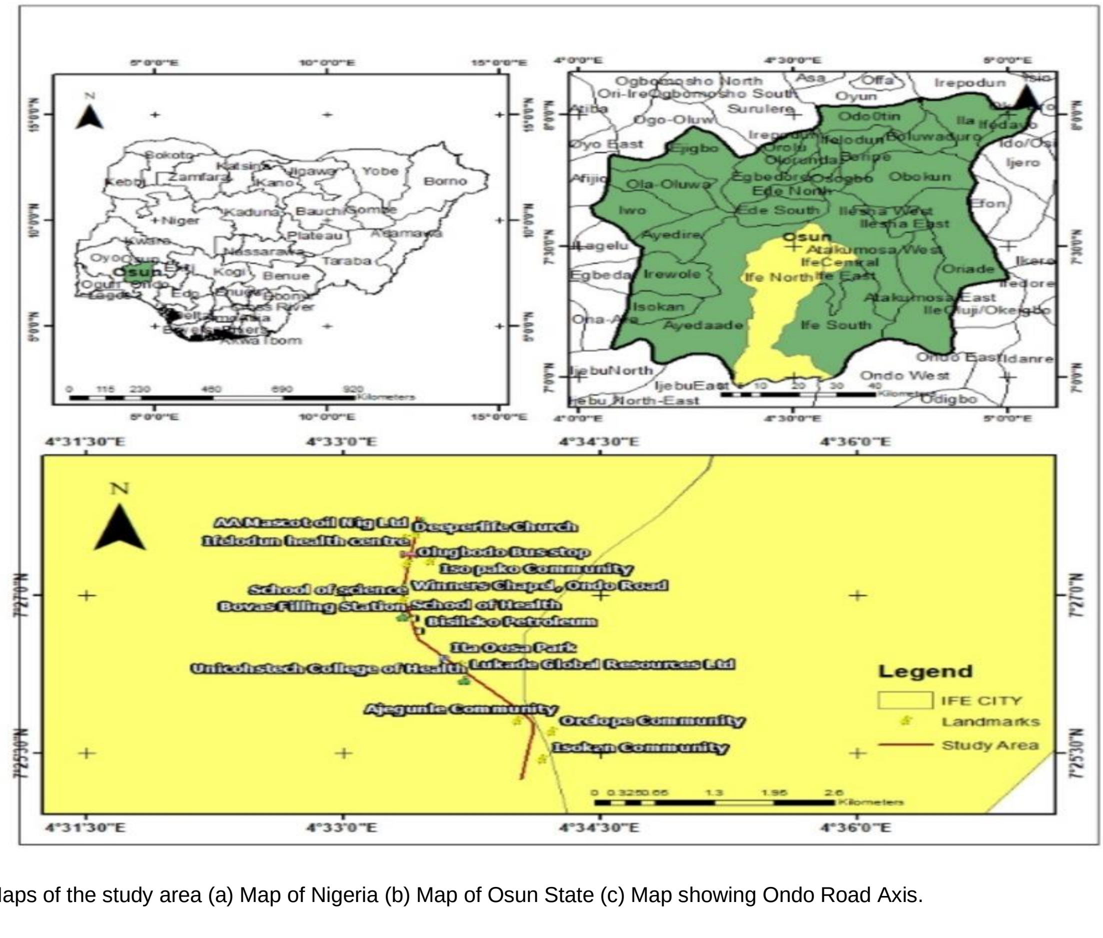


***Fig 1.0:*** Maps of the study area (a) Map of Nigeria (b) Map of Osun State (c) Map showing Ondo Road Axis.

## Data Collection

Collection of data for this study involved primary and secondary sources. Primary data were collected on coordinates of the locations of existing sawmills and sample points gotten through the use of DGPS (Tersus David) which was properly checked for higher accuracy before used. Secondary data were existing information which was gotten from Google Earth Imagery and Base map of the study area through Google Earth Pro and Open Street Map. The coordinates recorded from field survey were stored in a spreadsheet environment using Microsoft Excel and saved as CSV file. This file was then imported into ArcMap environment, with the data frame in the right coordinate system (i.e WGS 84 UTM ZONE 31N), the locations of each sawmill and sampling point was displayed using the Northings and Eastings. The displayed event was then exported as a point shape file using the coordinate system of data layer. With this, spatial distribution map of sample points within the study area was prepared. ArcGIS 10.7.1 and QGIS 3.12 were used for all the geo-processing steps. Coverage in this study comprised buildings and existing sawmills within 2km radius Area of Interest (AOI) while previous studies such as Olawuni & Okunola (2014a&b) and Akinbode & Olujimi (2014) made use of 0.9km and 1km respectively in their studies. Buffer zone were created for sawmills at 300m (0.3km) sawmill's buffer on the basis of international acceptable standard that is minimum sawmill distance to residential building (USEPA, 2014). This was stratified into three which were buffers below 100m, 101-200m and 201-300m zones that were given for location to determine their distances to air sample points in each of the selected four sawmill sites within the study area. These sawmill sites were Iso pako (Plank market), Ajegunle, Isokan and Orelope. This study engaged air monitoring by in situ method / determination. Device was calibrated in non-polluted area before used according to manufacturer standard and adequate precautions were also taken to ensure precision in whole process. In evaluating the air quality at each buffered zone in different sawmill sites within the study area, met one airborn particle counter hhpc6+ handed device was stationed at each location. The readings were observed and recorded after attaining very good accuracy within the minimum of twenty minutes in each point which amounted to one hour used in a sawmill site. Raimi et al (2020) represented each day for a period of one month on an alternate day. The particulate matters investigated upon were coarse and fine particles of 0.3µm, 0.5µm, 1.0µm, 2.0µm, 5.0µm and 10.0µm. The concentration of these particulate matters was measured in micromega per cubic meter (µg/m$^3$) while levels of air quality were compared with local (FEPA, 1998) and global (USEPA, 2024) allowable limits / standards of one-hour daily averaging.

## RESULTS AND DISCUSSION

Presented in this section are the result of the findings on concentrations of particulate matters in different sawmill sites in the study area in comparison with local and global standards. These are as shown in Table 1.0-4.0 below.

***Table 1.0:*** Air quality concentration levels at Iso pako (Plank market) Sawmill site

| Particulate matters | Readings at Below 100m zone (µg/m$^3$) | Readings at 101-200m zone (µg/m$^3$) | Readings at 201-300m zone (µg/m$^3$) | Standard / Limit | |
|---|---|---|---|---|---|
| | | | | Local | Global |
| | | | | FEPA limit | US EPA limit |
| 0.3µm | 4773 | 2366 | 1640 | 600(µg/m$^3$) | 250(µg/m$^3$) |
| 0.5µm | 330 | 208 | 134 | | |
| 1.0µm | 27 | 14 | 4 | | |
| 2.0µm | 14 | 4 | 1 | | |
| 5.0µm | 2 | 0.0 | 0 | | |
| 10.0µm | 0 | 0 | 0 | | |

Source: Author (2023)

Table 1.0 shows air quality concentration at Isopako sawmill site. Fine particulate matters of 0.3µm has the highest emission of particulate matter in this site with 4773µg/m$^3$ at below 100m buffered zone and 2366µg/m$^3$ at 101-200m buffered zone while 1640µgm$^3$ was recorded at 201-300m buffered zone. These values were above both local and global established standards. Particulate matter of 0.5µm at Isopako site accounted for 330µg/m$^3$ at below 100m buffered zone which was within the local limit and above the global standard. 208µg/m$^3$ and 134µg/m$^3$ respectively were recorded for buffered zones 101-200m and 201-300m. Below 100m buffered zone, particle of 1.0µm was 27µg/m$^3$ while at 101-200m and

201-300m buffered zones it exerted influent rate of 14µg/m³ and 4µg/m³ respectively on the air which were within both standards. Particulate matter of 2.0µm had emission rate that was below and within both standards in all zones at Isopako site just like coarse particles of 5.0µm and 10.0µm. Fine particulate matter of 0.3µm found itself remarkably higher above the standard limits in all zones within this site. The pattern of variability discovered in this site was "decreasing linear pattern" from close proximity to distant buffered zones. This pattern can be evident in the analysis from each buffered zone as shown in Table 1.0. The pattern shows that the concentration values of each particulate was decreasing horizontally from below 100m which was the closest buffered zone to the last zone of 201-300m. Therefore, this analysis affirmed that the closer the residents to sawmill industry, the poorer the quality of air inhaling by the public. This indicates that geographical differences abound in the air quality from one buffered zone to the other within this sawmill site. Findings from the study revealed that below 100m buffered zone has the highest concentration of emission in this sawmill site. This is consistent with Lala *et al* (2023) that majority of the dispersed particles are found within 100m.

***Table 2.0:*** Air quality concentration levels at Ajegunle sawmill site

| Particulate Matters | Readings at Below 100m zone(µg/m³) | Readings at 101-200m zone (µg/m³) | Readings at 201-300m zone (µg/m³) | Standards / Limits | |
|---|---|---|---|---|---|
| | | | | Local FEPA limit | Global US EPA limit |
| 0.3µm | 3228 | 2577 | 1954 | 600(µg/m³) | 250(µg/m³) |
| 0.5µm | 301 | 200 | 153 | | |
| 1.0µm | 10 | 9 | 6 | | |
| 2.0µm | 8 | 5 | 1 | | |
| 5.0µm | 0 | 0.0 | 0 | | |
| 10.0µm | 0 | 0 | 0 | | |

Source: Author (2023)

Considering Table 2.0 which is on air quality concentration levels at Ajegunle sawmill site, the fine particulate matters of 0.3µm also exceeded the one-hour daily limit for both local and global standards and this was so because of the high rate of dust dispersed into the air by sawmill activities in this site. As analyzed above 3228µg/m³, 2577µg/m³ and 1954µg/m³ were accountable for the emission discharged into the air by this particulate matter below 100m, 101-200m and 201-300m buffered zones in this site. Other fine particles such as 1.0µm and 2.0µm as shown from Table 2.0 discharges lesser volume of dust that is within the air quality limits into the atmosphere except 0.5µm that has 301µg/m³ below 100m which was higher than global standard. The coarse 5.0µm and 10.0µm had very less influence on emission generated in this site as reveals in the above analysis with 0.0µg/m³. This analysis follows the same pattern of relative decrease in the concentration of emission discharged into the air from buffered zone of close proximity to distant zones to the sawmill which might account for the same glitches on the residents and the environment. This result therefore established the spatial variation of emission exerted at different zones within sawmill sites in the study area which was also in support of Olawuni & Akinola (2014b) that there was a significant difference between residences of varying distances from sawmills and severity of smoke.

***Table 3.0:*** Air quality concentration level at Isokan sawmill site.

| Particulate Matters | Readings at Below 100m zone (µg/m³) | Readings at 101-200m zone (µg/m³) | Readings at 201-300m zone (µg/m³) | Standards / Limits | |
|---|---|---|---|---|---|
| | | | | Local FEPA limit | Global US EPA limit |
| 0.3µm | 3143 | 2166 | 1875 | 600(µg/m³) | 250(µg/m³) |
| 0.5µm | 298 | 191 | 122 | | |
| 1.0µm | 35 | 13 | 7 | | |
| 2.0µm | 5 | 2 | 1.2 | | |
| 5.0µm | 0 | 0 | 0 | | |
| 10.0µm | 0 | 0 | 0 | | |

Source: Author (2023)

Table 3.0 also reveals higher volume of 0.3µm in the buffered zones of Isokan sawmill site with 3143 µg/m³, 2166 µg/m³ and 1875 µg/m³ respectively. Other fine particulate matters were found had their concentrations in conformity with both standards with the exception of 0.5µm that has 298µg/m³ for below

100m buffered zone and this only conforms to local standards without meeting up with global limit. There was a significant decrease in the concentration of 1.0µm below 100m buffered zone from 35µg/m$^3$ to 13µg/m$^3$ and 7µg/m$^3$ in 200m and 300m buffered zones respectively. Likewise, there was a relative decrease in the concentration of 2.0µm from 5µg/m$^3$ below 100m zone to 2µg/m$^3$ and 1.2µg/m$^3$ respectively for zone 101-200m and 201-300m. The coarse particulate matters of 5.0µm and 10.0µm were all found to be 0.0µg/m$^3$ in all zones which exerts very little or no effect on the environment thereby maintains their conformity with both local and global standards. Therefore, above analysis shows a relative decrease in the values of particles from below 100m buffered zone of close proximity to distant zone of 300m to sawmill. This however, established why there will be much consequence of activities of sawmill on the residents living within the buffered zones of close proximity to sawmill. It could be inferred from above analysis that possibility abounds of difference in health challenges due to variability in the air quality levels from one buffered zone to other. It is believed that this effect can have influence on the surrounding neighborhoods. This substantiates the result of Bell (2013) that there is no threshold under which pollutant exerts no adverse effects.

***Table 4.0**:* Air quality concentration levels at Orelope sawmill site.

| Particulate Matters | Readings at Below 100m zone (µg/m$^3$) | Readings at 101-200m zone (µg/m$^3$) | Readings at 201-300m zone (µg/m$^3$) | Standard / Limit | |
|---|---|---|---|---|---|
| | | | | Local FEPA limit | Global US EPA limit |
| 0.3µm | 48152 | 1529 | 1495 | 600(µg/m$^3$) | 250(µg/m$^3$) |
| 0.5µm | 9063 | 135 | 145 | | |
| 1.0µm | 3855 | 12 | 13 | | |
| 2.0µm | 294 | 6 | 3 | | |
| 5.0µm | 127 | 2 | 0 | | |
| 10.0µm | 8 | 0 | 0 | | |

Source: Author (2023)

Observation from table 4.0 shows air quality concentration levels at Orelope site. The concentrations of 0.3µm, 0.5µm and 1.0µm were all seriously higher than the required one-hour daily limit for both standards below 100m buffered zone with 48152µg/m$^3$, 9063µg/m$^3$ and 3855µg/m$^3$ respectively, while 2.0µm particle had 294µg/m$^3$ which was only higher than the global standard and fall within the local limit. In this zone only 5.0µm and 10.0µm with 127µg/m$^3$and 8µg/m$^3$ were within tolerable limit of both standards. At buffered zones 101-200m and 201-300m, fine particulate matter of 0. 3µm was also found above the local and global standards these are with 1529 µg/m$^3$ and 1495 µg/m$^3$. As shown above the influence of coarse particles of 5.0µm and 10.0µm is relatively higher in this site than others sites especially below 100m buffered zone but they still exerts effect that is within the tolerable limits. The rate of emission of particulate matters is worrisome in this sawmill site as they found to be far exceeded the established standards necessary to protect residents' well-being particularly that of 0.3µm. The highest amount of concentration of particulate matters recorded in this site especially below 100m buffered zone may be attributed to the huge input of emission from activities of sawmills in the study area. This great upsurge in the concentration of 0.3µm and 0.5µm at Orelope sawmill site was a serious concern, this might be linked to the presence of more particulate matter sources such as dust, waste burning, bacterial fragments and fumes from engine combustion process in this sawmill site. This result supports the assertion that chief culprits in causing premature death from outdoor air pollution yearly are the fine particles with a diameter of 2.5 or less (Tao *et al* 2018, WHO 2018, WHO 2021). These studies have linked increased in fine particulates matters concentrations to have cause elevated susceptibility to respiratory diseases such as acute respiratory distress, asthma, lung cancer and so on. The result of this study also correlates with above findings with 0.3µm significantly above the FEPA and USEPA standards while 0.5µm, 1.0µm and 2.0µm only higher than FEPA standard. This indicates that this environment has met the "higher health category" in terms of fine particulate matters. With this, air quality can be considered unhealthy for the residents of different buffered zones within this sawmill site and general public. This aligns with Tao *et al* (2018) that smaller particles pose a great risk than larger ones. Therefore, people experiencing greater adverse effects from $PM_{2.5}$ or less than $PM_{10}$ in the light of air pollution in the study area. This causes great apprehension that needs to be arrested timely in this environment. However, the study resulted in "low health category" for the environment in considering coarse particulates of 5.0µm and 10.0µm. Both coarse particulates investigated were significantly lower than FEPA and

USEPA recommended standards in all sawmill sites. This result is consistent with Raimi *et al* (2020) and contradicts (Karr *et al*, 2007) that prolonged exposure to high concentration level of $PM_{10}$ may cause throat and lung irritation, bronchitis and possibly premature death. Nonetheless, the actual health damage cause by dust particles depends upon its nature and composition (Raimi *et al*, 2020). Spatial distribution of air points sampled within the sawmill sites in the study area is as shown in Figure 2.0.

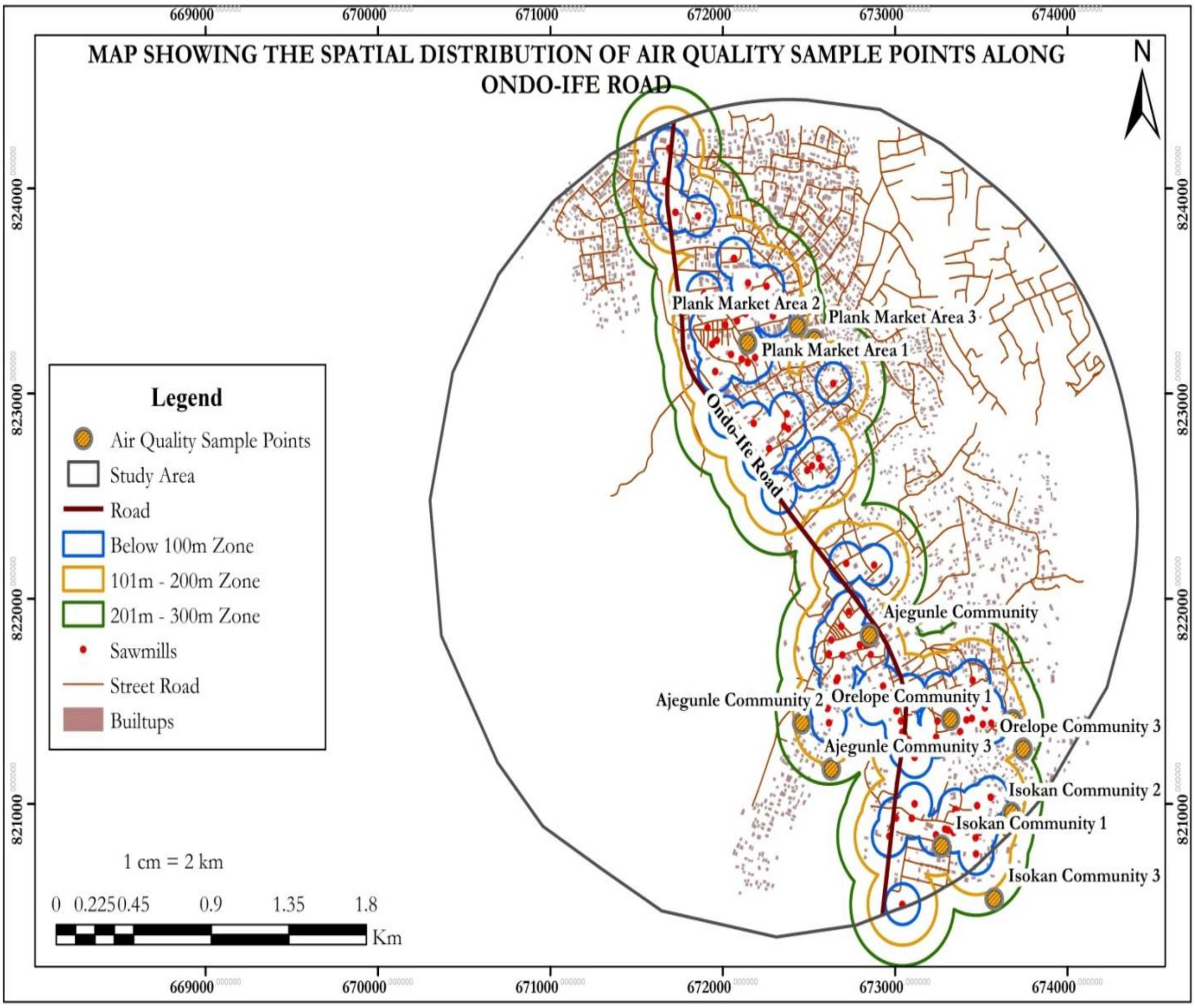


***Fig 2.0***: Spatial distribution of air points sampled within sawmill sites

## Conclusions

The spatial investigation into ambient air quality in sawmill environment of Ondo Road, Ile-Ife, Osun state has been conducted. The study showed that air depicted relatively unhealthful substance as a response to the influence of the presence of particulate matters sources in this environment. Study recognized fine particulate matters as having much negative influence on the environment than the coarse particles in buffered zones of different sawmill sites. Hence, their levels exceeded both local and international established standards with some exceptions. In essence fine particulates exerted higher negative effect on residents' health while coarse particles were of low health category in the study area that maintained conformity with both recommended standards. The result obtained established that there was a significant variation in the levels of ambient air quality within sawmills sites. This indicated geographical difference of air quality within different sawmill sites in the study area. This is with "decreasing linear pattern" of variability. These findings validated why it is necessary for stakeholders in environmental management to pay proper attention to this area because particulate matters and public are at variance to each other. The study therefore, recommends formation of community engagement committee that will see to proper orientation of public on how to enhance and protect themselves against particulates and stakeholders in environmental agencies should be alive to their responsibilities by majorly engage in aggressive control in preventing fine particles from becoming airborne in the study area.

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