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Assessment Of Ambient Air Within the Vicinity of Charcoal Production Site In Kunguni Community, Kwali Area Council in Abuja, Nigeria

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Abstract

Charcoal production is a prevalent practice in many communities, and its impact on local air quality is a growing concern. This study investigates the presence and spatial distribution of air pollutants in a producing community within a 200-meter radius in Kunguni, Kwali Area Council, Nigeria. The study assessed ambient air quality, pollutant levels (NO_2, SO_2, CO, NH_3, H_2S, $PM_{2.5}$, and PM_{10}), and their variation across different sampling points and times. The study utilized an experimental research design and collected primary data from the charcoal production community. Data analysis involved techniques like linear regression and time series regression to understand spatial and temporal patterns. Key findings include the absence of NO_2 and NH_3 emissions from charcoal production, while H_2S concentrations remained within permissible limits. The concentrations of SO_2, CO, $PM_{2.5}$, and PM_{10} were notably elevated across sampling points, often exceeding permissible limits. Consequently, the study underscores the potential health risks faced by both charcoal producers and residents in the Kunguni community due to pollutant inhalation, which could lead to respiratory and cardiovascular issues. This research emphasizes the need for better air quality management in the charcoal-producing region, addressing pollutants like SO_2, CO, $PM_{2.5}$, and PM_{10} to safeguard public health and reduce associated risks. This study also serves as a stark reminder of the critical importance of addressing air pollution at its source to protect both human health and the environment.

Keywords: Charcoal, Ambient, Air Quality, Vicinity, pollutant level.

INTRODUCTION

Air is an invisible substance surrounding the earth and providing us all with the breathable oxygen and performs a vital role in supporting life but with the passage of time the pure air is gradually getting contaminated due to an increase in air pollution (Nitesh, Divyanshu , Punya and Namit, 2021). Air pollution is a major problem all over the world in both developed and developing countries. The rapid increase in population and demand for energy has resulted in emission of toxic air pollutants that affect the surrounding environment as well as human health in low, middle, and high-income countries (Ruiting Fei, Guangzhi Di, Haiyan Cheng (2022). Ambient air pollution in both cities and rural areas

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was estimated to cause 4.2 million premature deaths worldwide per year in 2019; this mortality is due to exposure to fine particulate matter, which causes cardiovascular and respiratory disease, and cancers (WHO, 2020).

The issue of air pollution is one that needs to be resolved on a global scale (Joaquim, Jose, and Marta, 2020). Carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), hydrogen sulphide (H_2O), ammonia (NH_3), particulate matter (PM) less than 10 microns (PM_{10}), and particulate matter less than 2.5 microns ($PM_{2.5}$) are the primary pollutants that are damaging to human health and well-being (WHO, 2022). The World Health Organization (WHO) found in 2016 that air pollution caused 4.2 million premature deaths per year in cities and rural areas of low- and middle-income nations, with exposure to $PM_{2.5}$ being the cause (Omnya, 2019).

As one of the environments for human survival, the atmospheric environment has been affecting the quality of people's lives. The problem of air pollution has attracted the attention of all sectors of society. At the same time, it is also the research hotspot of geography, ecology, environmental science, and other disciplines (Song., 2017; Mohammad, *et. al.*, 2020). Some studies have found that the industrialization process affects many factors affecting air quality (Chang, Li and Zhang, 2021), such as population, industrial structure, urbanization level, and economic development. Industrial soot emissions and per capita GDP are powerful the strong influencing factors of air quality.

The majority of the wood that is removed from forests across the world is used for energy production, primarily for cooking and heating in impoverished nations but also for the production of electricity in industrialized nations. In Africa and Asia, more than 60% of energy consumption is derived from wood gathering. An estimated 17% of the wood used as fuel worldwide is turned into charcoal (WHO, 2021). Charcoal is one of the most basic household energy sources in most developing countries. The use of charcoal for household energy is still prevalent today because it accounts for 14% of all domestic energy worldwide (Chidumayo & Gumbo, 2013). Additionally, its production boosts employment, tax revenue, and rural incomes thereby increasing the profitability of charcoal production (Onekon & Kipchirchir, 2012).

Due to its use in both rural and urban communities, African nations account for over 63% of the world's charcoal production (Gazull & Gautier, 2015). This phase of this traditional energy supply chain is said to be the most environmentally damaging (Arnold, Kohlin and Persson, 2006; Zulu , Leo, & Richardson, 2013). Charcoal provides a lifeline for the rapidly growing populations in the region's metropolitan areas, as well as potentially major segments of the rural population, as it's a conventional fuel that has been utilized for hundreds of years. In Nigeria, due to its accessibility, lack of bulk, ease of transportation, and cleaner (smokeless) burn, charcoal is widely used in both rural and urban areas. In addition to benefits for household usage, it considerably improves the country's energy balance. In addition, it provides an alternative to more expensive home energy sources and a source of household income (Olarinde & Olusola, 2018).

Charcoal production leads to local and regional environmental pollution and loss of forest resources (Alem, Duraisamy, Legesse, and Seboka, 2010). Charcoal discharge significant amounts of particulates, carbon monoxide, nitrogen dioxide and sulfur dioxide. These emissions significantly alter the physical and chemical characteristics of the atmosphere and contribute to global warming (Chidumayo and Gumbo, 2013). Furthermore, emissions during charcoal production affect human health both the employees and inhabitants of communities (Orru, *et. al.,* 2010; Abidin, *et. al.*, 2014). Given the environmental and occupational impacts caused by charcoal production, this study was designed to determine the presence of air pollutants in significant concentrations in charcoal producing vicinity of Kunguni community, Kwali Area Council in the Federal Capital Territory of Nigeria.

METHODOLOGY

Description of Study Area

This study was carried out at Kunguni community in Kwali Area Council, in the Federal Capital Territory FCT, Abuja. Kunguni is a village in Kudu ward of Kwali Area Council of the Federal Capital Territory (FCT) of Nigeria. The absolute location of Kunguni is latitude of 8° 52' 56,17''N and a longitude of 6° 53' 49,99''E (See Figure 1 and 2). Kwali has a distinct wet (March - October) and dry (November - February) seasons with average annual rainfall of 1358.7mm and mean temperature range of between 20.70C-30.80C. Rainfall plays a vital role with respect to agricultural activities within the study area and most farming activities highly depend on rainfall (Ishaya, *et. al.,* 2013). About 60% of the annual rains fall during July to September. Relative humidity (RH) is lowest in the drier months of November to March, with about 10% being recorded in February. The study area has a long term mean temperature in the study area ranges from 30ºC-37ºC yearly and means total annual rainfall of approximately1,650mm per annum (Ishaya and Emmanuel, 2022).

The study area falls within the Guinea savannah ecological region. The vegetation combines the best features of the southern tropical rain forest and guinea savanna of the North while the soil is reddish with isolated hills filled by plains and drained sandy clay loam which supports farming of the major crops such as sorghum, millet, melon, yam, soybean, benniseed, cassava and rice cultivation (Abuja ADP, 2004). The soils in Kunguni in Kwali Area Council are also, generally shallow and sandy in nature, especially on the major plains such as Iku-Gurara. The high sand content makes the soils to be highly erodible. The shallow depths is a reflection of the presence of stony lower horizons, which shows a high level of variability comprising mainly of sand, silt, clay and gravel (Abalaka and Kebiru, 2019).

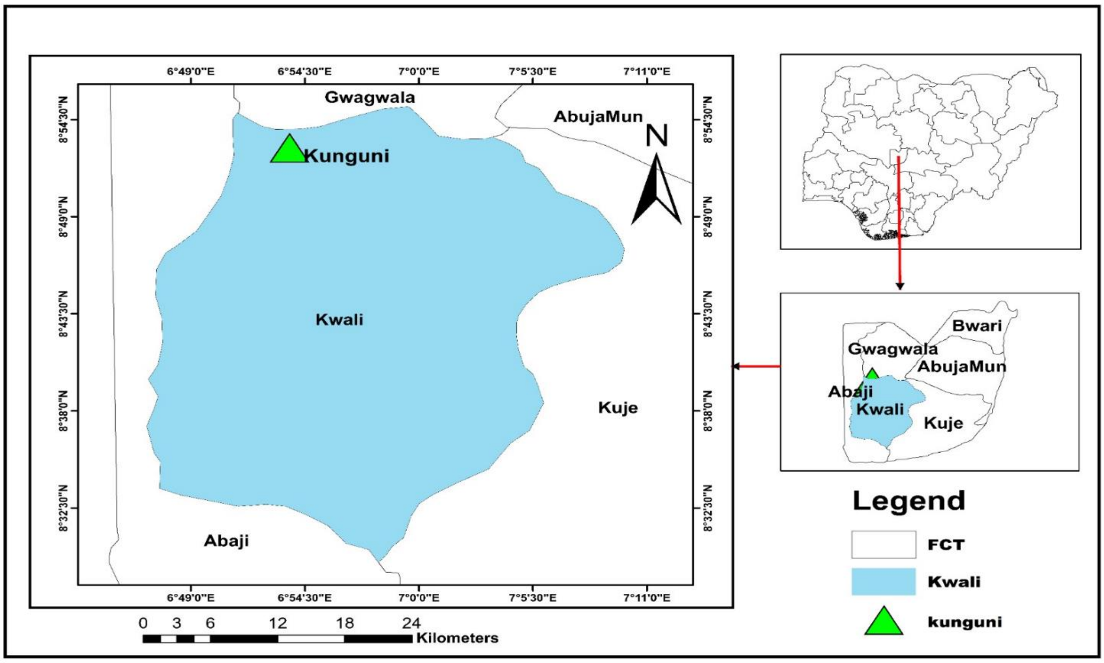


Figure 1: Map of Kwali showing Kunguni.

Figure 2: Satellite image of the study area (Kunguni).

Kunguni community is known for charcoal production. The use of charcoal is associated with poverty and low-income jobs earnings among residents and the mass production could also be associated with joblessness among residents as the Area Council is lacking in employment opportunities compared to other Area Councils in the FCT in terms of development and economic activities. As a result of this, many residents depend on the production of charcoal for their livelihood as well cultivation of a number of crops such as, maize, egusi, millet and benni seed amongst others and also hosting a number of markets such as; charcoal market (Balogun, 2001; Abalaka and Kebiru, 2019).

Methods

An experimental research design was adopted in this study. It investigated the presence of pollutants in the air as a result of charcoal production community of Kunguni in Kwali Area Council of the Federal Capital Territory of Nigeria. The methodology of the study centred on basically the "what", "when", "where" and "how" of the research subject.

Data was primarily sourced towards addressing set objectives and hypotheses of the study. Consequently, the data collected for this research is for air pollution parameters such as; NH_3 (Ammonia), NO_2, (Nitrogen Dioxide), H_2S (hydrogen sulphide), CO (Carbon monoxide), SO_2 (Sulphur dioxide), PM_{10} (Particulate Matter 10 Micrometers) and $PM_{2.5}$ (Particulate Matter 2.5 Micrometers) from the charcoal production community of Kunguni in Kwali Area Council of the Federal Capital Territory of Nigeria. These were collected from sample points in and around charcoal production community of Kunguni community using MiniVol Portable Air Sampler as well as a set of Crow Can gas detector meters (See Table 1). In addition, the Geographic Positioning System 60cx (GPS) was also used to get the actual coordinates of the sampling points of interest during data collection. The air quality collection exercise was carried out at 7am, 9am, 11am, 1pm, 3pm and 5pm to ascertain the concentration of parameters.

Table 1: List of Instruments

S/N	Instruments Model	Usage	Types
1.	Garmin® GPSMAP® 60Cx	Global Position System	UTM, Longitude, and Latitude Coordinates
2.	BW Technologies GasAlert® MicroClip	Gases Detection Instrument	CO, SO_2, CH_4, LEL, and H_2S
3.	RKI GX-2009 multi-Gas	Gases Detection Instrument	CO, SO_2, CH_4, LEL, and H_2S

Source: Researcher Compilation, 2023.

Systematic sampling was used in the selection of assessment locations. The air quality data was collected from five sampling points at 50 meters intervals from charcoal production community of Kunguni in Kwali Area Council of the Federal Capital Territory of Nigeria. Air quality assessments were carried out at the five sampling points at 7am, 9am, 11am, 1pm, 3pm and 5pm. This allows for comparative assessment of air quality at different location and at different times of the day in the charcoal production community of Kunguni Community. The collection of air quality data for this study was carried out in May 2023. During data collection, locations were geo-referenced using GPS, in addition, the site characteristics of each location was noted during data collection to relate variation in the air quality of site factors.

Table 2: Sample communities and locations

Sampling Stations	Distance from Production Site (m)	Latitude	Longitude	Elevation (m)
SP1	0	8.88168239	6.89514808	179
SP2	50	8.88167043	6.89558544	157
SP3	100	8.88188284	6.89593072	162
SP4	150	8.88183341	6.89644449	159
SP5	200	8.88189691	6.89682993	140

Source: Researcher compilations, 2022.

Based on the type of data gathered in this study, both descriptive and inferential statistical tools were used to analyze and explain the data obtained. A descriptive statistical tool such linear, time series regression were used for data interpretation and understanding spatial and temporal understanding of the air quality. A Post Hoc Test was used to ascertain ambient air pollution variation between sample points and the time of the day in charcoal production community of Kunguni. The Post Hoc tests conducted expressed the differences between locations, testing each possible pair of locations. This is an "after the fact test" specifically carried out after a significant ANOVA result.

Table 3: FMEnv/NESREA Permissible limits air quality

Parameter	FMEnv/NESREA	
	Limit	Time Average
NH_3 (Ammonia)	0.09	One hour
CO (Carbon monoxide)	4.36 ppm	One hour
NO_2 (Nitrogen Dioxide)	0.06	One hour
SO_2 (Sulphur dioxide)	0.05ppm	One hour
H_2S (Hydrogen sulphide)	5ppm	One hour
$PM_{2.5}$	40 ug/m^3	One hour
PM_{10}	150 ug/m^3	One hour

Source: Researcher compilation 2023.

RESULTS AND DISCUSSION

Diurnal distribution of ambient air quality at charcoal production area

The result of ambient concentration of hydrogen sulphide (H_2S), Carbon monoxide (CO), Sulphur dioxide (SO_2), Carbon Dioxide (CO_2), Ammonia (NH_3), Particulate Matter 10 (PM_{10}) and Particulate Matter 2.5 ($PM_{2.5}$) for the five sampling points at 7am, 9am, 11am, 1pm, 3pm and 5pm are presented. H_2S, and SO_2 were not observed in most sampling points and based on this, trend line equation, R^2 equations and Post Hoc analysis were not carried out on the data instead results were presented graphically only. NO_2, and NH_3 were not traced in the air hence no result was presented.

Spatial and temporal concentration of $PM_{2.5}$ at Kunguni charcoal production area

The air pollution data collected at 7am from five sampling points at 50 meters intervals from charcoal production community of Kunguni shows that highest concentration of $PM_{2.5}$ (812.6 ug/m^3) was recorded at the charcoal production takes place followed by the second sampling point 50 meters away from charcoal production site with $PM_{2.5}$ value of 151.2.6 ug/m^3 while the least was recorded at the fifth sampling point 200 meters away from charcoal production site with $PM_{2.5}$ value of 22 ug/m^3 (See Figure 4 and Table 4).

At 9am, the highest concentration of $PM_{2.5}$ (1015.2 ug/m^3) was observed at the charcoal is produced followed by the second sampling point 50 meters away from charcoal production site with $PM_{2.5}$ value of 166.8 ug/m^3 while the lest was recorded at the fifth sampling point 200 meters away from charcoal production site with $PM_{2.5}$ value of 64.9 ug/m^3. The highest concentration of $PM_{2.5}$ at 11am was 1257.2 ug/m^3 at the first sampling point where charcoal is produced followed by the second sampling point 50 meters away from charcoal production site with $PM_{2.5}$ value 170.1 ug/m^3 while the last was recorded at the fifth sampling point 200 meters away from charcoal production site with $PM_{2.5}$ value of 68.93 ug/m^3. At 1pm the same day, also the highest concentration $PM_{2.5}$ (1022.7 ug/m^3) was recorded at the charcoal production site followed by the concentration of $PM_{2.5}$ at 50 meters away the from charcoal production site with a value of 202.5 ug/m^{3}while the lowest concentration of $PM_{2.5}$ (118.4 ug/m^3) was observed at the fifth sampling point which is 200 meters away from the charcoal production site (See Figure 4 and Table 4).

At 3pm, the highest concentration of $PM_{2.5}$ (831.8 ug/m^3) was observed at the charcoal production site followed by the second sampling point 50 meters away from charcoal production site with $PM_{2.5}$ value 166.8 ug/m^3 while the lowest was recorded at the third sampling point 100 meters away from charcoal production site with $PM_{2.5}$ value of 65.4 ug/m^3. By 5pm, the highest concentration of $PM_{2.5}$ (831.8 ug/m^3) was also observed at the charcoal production site followed by the fourth sampling point 200 meters away from charcoal production site with $PM_{2.5}$ value of 166.8 ug/m^3 while the lowest was recorded at the second sampling point 50 meters away from the charcoal production site with $PM_{2.5}$ value of ug/m^3 (See Figure 4 and Table 4).

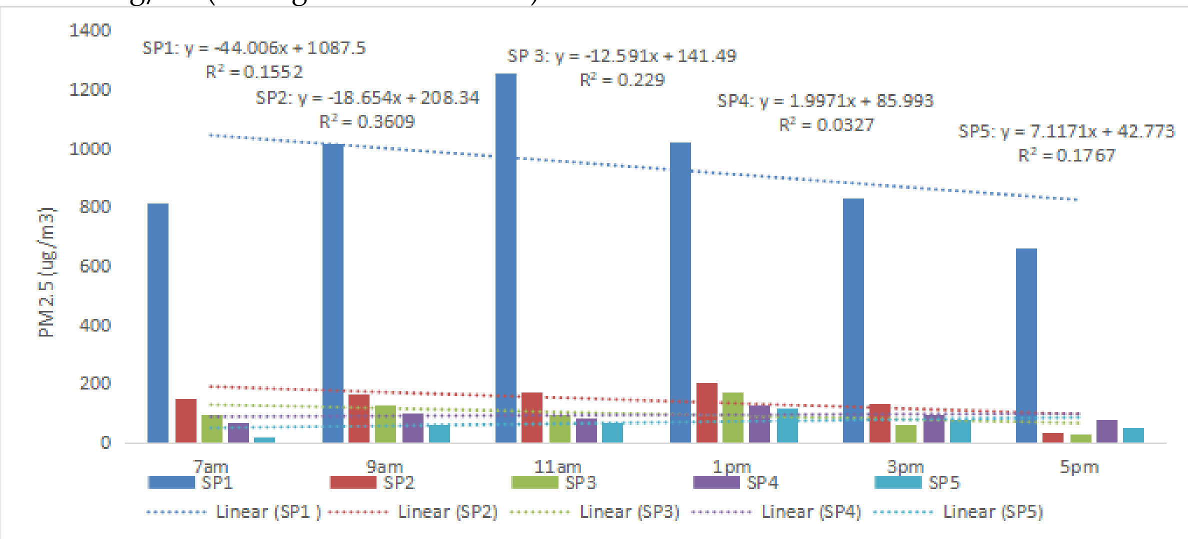


Figure 4: Spatial and temporal concentration of $PM_{2.5}$ at Kunguni charcoal production area
Source: Researcher Fieldwork, 2023

Over the time of the day at the charcoal production site, $PM_{2.5}$ was at its highest level (1257.2 ug/m^3) at 11am, followed by 1022.7 ppm at 1pm, 1015.2 ug/m^3 at 9am with the least (661.5

ug/m^3) and 812.6 ug/m^3 at 7am with a trend line equation of $y = -44.000x + 1087.5$ predicting a diurnal decrease in the concentration of $PM_{2.5}$ while the R^2 is 0.1552 (15.502%) which is at relatively weak correlation between time of the day with ambient concentration of $PM_{2.5.}$ At the second sampling point, 50 meters away from the charcoal production site, the $PM_{2.5}$ was at its highest level (202.5 ug/m^3) at 1pm, 170.1 ug/m^3 at 11am, 166.6 ug/m^3 at 9am, 151.2 ug/m^3 at 7am with the least (34 ug/m^3) at 5pm having a trend line equation of $y = -18.654x + 208.34$ predicting a gradual decrease in the concentration of $PM_{2.5}$ while the R^2 is 0.3609 (36.09%) depicting slight correlation between time of the day with ambient concentration of $PM_{2.5}$. At the third sampling point (100 meters away from the charcoal production area), $PM_{2.5}$ was at its peak (171.6 ug/m^3) at 1pm, 128.4 ug/m^3 at 9am, 95.3.6 ug/m^3 at 7am, 94.3 ug/m^3 at 11am, 65.4 ug/m^3 at 3pm and the least (295 ug/m^3) at 5pm having trend line equation of $y = -12.591x + 141.49$ predicts noticeable diurnal decrease in the concentration of $PM_{2.5}$ with R^2 value of 0.229 (22.9%) given is a weak positive correlation between time of the day with ambient concentration of $PM_{2.5}$ (See Figure 4 and Table 4).

The findings at the fourth sampling point show that the highest (129.8 ug/m^3) concentration of $PM_{2.5}$ was recorded at 1pm, 99.6 ug/m^3 at 9am, 93.8 at 3pm, 84 ug/m^3 at 11am and least (71.2 ug/m^3) was recorded early in the morning by 7am. The trend line equation $y = 1.971x + 85.993$ predicts an infinitesimal diurnal decrease in the concentration of $PM_{2.5}$ with R^2 of 0.0327 (3.27%) depicting a weak positive correlation between time of the day with ambient concentration of $PM_{2.5.}$ At the fifth sampling point, 200 meters away from the charcoal production site, $PM_{2.5}$ was at its highest level (111.4 ug/m^3) at 1pm, 79.4 ug/m^3 at 3pm, 68.3 ug/m^3 at 11am, 64.9 ug/m^3 at 9am, 53.1 at 5pm and the least (22 ug/m^3) at 5am with a trend line equation of $y = 7.1171x+ 428.773$ predicting a gradual increase in the concentration of $PM_{2.5}$ while the R^2 is 0.1767 (17.67%) (See Figure 4 and Table 4).

Spatial and temporal concentration of PM_{10} at Kunguni charcoal production area

Findings depict that the highest concentration of PM_{10} (947.4 ug/m^3) was recorded at the first sampling point where charcoal production takes place followed by the second sampling point 50 meters away from the charcoal production site with PM_{10} value of 176.8 ug/m^3 while the least was recorded at the fifth sampling point 200 meters away from charcoal production site with PM_{10} value of 35.2 ug/m^3. It was observed that at 9am, the highest concentration of PM_{10} (1234.9 ug/m^3) was at the first sampling point where charcoal is produced followed by the second sampling point 50 meters away from the charcoal production site with PM_{10} value of 207.4 ppm while the lest was recorded at the fifth sampling point 200 meters away from charcoal production site with PM_{10} value of 71.2 ug/m^3 (See Figure 5and Table 4).

At 11am, the highest concentration of PM_{10} was 1338.6 ppm at the first sampling point where charcoal is produced followed by the second sampling point 50 meters away the from charcoal production site with PM_{10} value of 223.5 ug/m^3 while the least was recorded at the fifth sampling point 200 meters away from the charcoal production site with PM_{10} value of 72.2 ug/m^3. By 1pm same day, the highest concentration PM_{10} (1370.5 ug/m^3) was recorded at the charcoal production site followed by the concentration of PM_{10} at 50 meters away from the charcoal production site with a value of 2597.5 ug/m^3 while the lest concentration of PM_{10} (123.8 ug/m^3) was observed at the fifth sampling point which is 200 meters away from the charcoal production site (See Figure 5 and Table 4).

Findings shows that at 3pm, the highest concentration of PM_{10} (917 ug/m^3) equally was observed at the charcoal production site followed by the second sampling point 50 meters away from the charcoal production site with PM_{10} value of 188.3 ug/m^3 while the lowest was recorded at the third sampling point 100 meters away from the charcoal production site with PM_{10} value of 76.6 ug/m³. At 5pm, the highest concentration of PM_{10} (729.7 ug/m³) was observed at the charcoal production site followed by the fourth sampling point 150 meters away from the charcoal production site with PM_{10} value of 82.8 ug/m³ while the lowest was recorded at the third sampling point 100 meters away from the charcoal production site with PM_{10} value of 34 ug/m³ (See Figure 4 and Table 4).

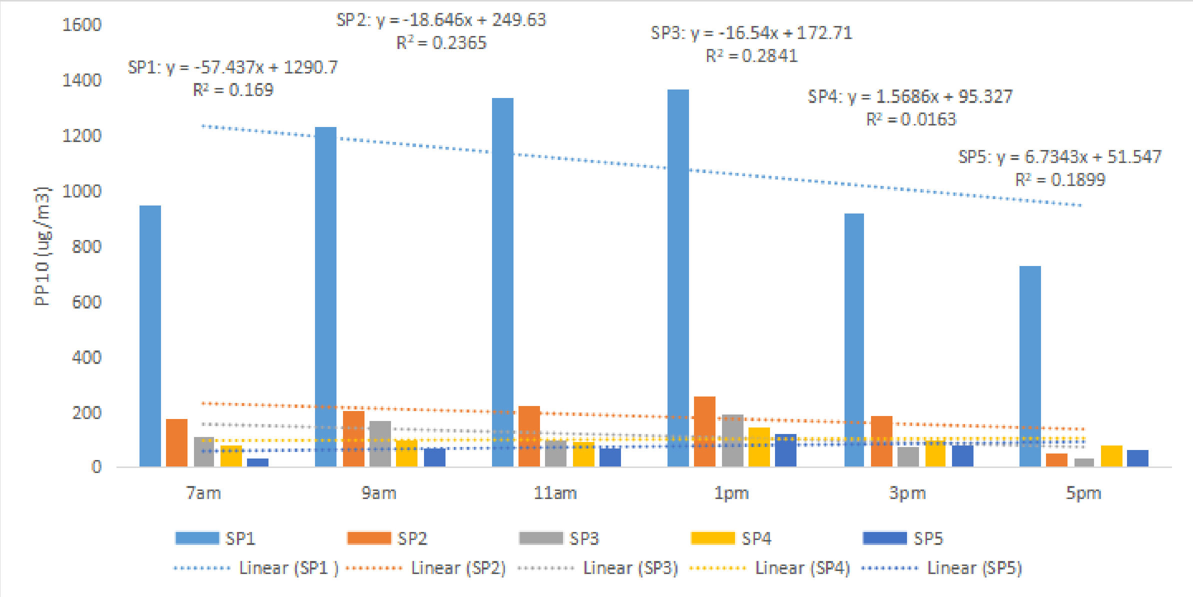


Figure 5: Spatial and temporal concentration of PM_{10} at Kunguni charcoal production area
Source: Researcher Fieldwork, 2023

At the first sampling point, the assessment of PM_{10} over the daytime at the charcoal production site depicts that PM_{10} was at its highest level (1370.5 ug/m³) at 1pm, followed by 10338.6 ug/m³ at 11am, 1234.9 ppm at 9am, 947.4 ppm at 7am, with the least (729.7 ug/m³) and 917 ug/m³ at 3pm having a trend line equation of $y = -57.437x + 1290.7$ predicting a diurnal decrease in the concentration of PM_{10} while the R^2 is 0.169 (16.9%) which is at relatively weak correlation between time of the day with ambient concentration of PM_{10}. At the second sampling point 50 meters away from the charcoal production site, PM_{10} was at its highest level (259.7 ug/m³) at 1pm, 223.5 ug/m³ at 11am, 207.4 ug/m³ at 9am, 188.3 ug/m³ at 3pm with the least (50.5 ug/m³) at 5pm and 178.8 ug/m³ at 7am having a trend line equation of $y = -18.646x + 249.63$ predicting a gradual decrease in the concentration of PM_{10} while the R^2 is 0.2365 (23.65%) depicting slight correlation between time of the day with ambient concentration of PM_{10} (See Figure 5 and Table 4).

Result at the third sampling point 100 meters away from the charcoal production area shows that PM_{10} was at its peak (192.2 ug/m³) at 1pm, 168.7 ug/m³ at 9am, 113.5 ug/m³ at 7am, 102.8 ug/m³ at 11am, 76.6 ug/m³ at 3pm and the least (35.1 ug/m³) was observed at 5pm with a trend line equation of $y = -16.54x + 172.71$) predicting noticeable diurnal decrease in the concentration of $PM_{2.5}$ with R^2 of 0.2841 (28.41%) given is a mild correlation between time of the day with ambient concentration of PM_{10}. The findings at the fourth sampling point shows that the highest (144.4 ug/m³) concentration of PM_{10} was recorded at 1pm, 102.2 ug/m³ at 3am, 101.5 at 9am, 93.1 ug/m³ at 11am, 82.8 ug/m³ at 5pm and the least (81.9 ug/m³) was recorded early in the morning by 7am. The trend line equation $y = 1.5686x + 95.327$ predicts an infinitesimal diurnal decrease in the concentration of PM_{10} with R^2 of 0.0163 (1.63%) depicting a weak correlation between time of the day with ambient concentration of PM_{10}. At the fifth sampling point, 200 meters away from the charcoal production site, PM_{10} was at its highest level (123.8 ug/m³) at 1pm, 83.9 ug/m³ at 3pm, 72.2.3 ug/m³ at 11am, 71.2 ug/m³ at 9am, 64.4 at 5pm and the least (35.2 ug/m³) was recorded at 7am with a trend line equation of y = 6.7343x+ 51.547 predicting a gradual increase in the concentration of PM_{10} having R^2 = 0.1899 (18.99%) (See Figure 5 and Table 4).

Spatial and temporal concentration of CO at Kunguni charcoal production area

Findings depict an uncommon observation of carbon monoxide (CO) at the Kunguni charcoal production community of Kwali Area Council. At the first sampling point, findings depict that at 7am CO was observed at only the first and second sampling point with CO values of 135 ppm and 10 ppm respectively. At 9am, the concentration of CO was also noticed only at charcoal production site (first sampling point) with CO value of 171 ppm and the second sampling point which is 50 meters away from the production site having CO concentration of 26 ppm. The highest concentration CO was recorded at 11am with the first sampling point where charcoal production takes place having 215 ppm, the sampling (50 meters away) having 127 ppm, the third sampling point (100 meters away) having 88 ppm, the fourth sampling point (150 meters away from production site) having having 36 ppm while the fifth sampling point had 21 ppm concentration of CO. It was observed at 1pm that CO concentration at the first sampling point was 196 ppm, 96 ppm at second sampling point, 73 ppm at the third sampling point, 56 ppm at the fourth sampling point and 44 ppm at the fifth sampling point (See Figure 6 and Table 4).

It was observed that at 3pm, the highest concentration of CO was observed at the first sampling point where charcoal is produced is produced with 72 ppm followed by the second sampling point 50 meters away from charcoal production site with CO value of 28 ppm while the lest was recorded at the fifth sampling point 200 meters away from the charcoal production site with CO value of 3 ppm. At 5pm, the CO value was 67 ppm at the first sampling point, 18 ppm at the second sampling point, 3 ppm at the third sampling point, 1 ppm at the 4 sampling point and CO was not detected at the fifth sampling point which is 200 meters away from the charcoal production site (See Figure 6 and Table 4).

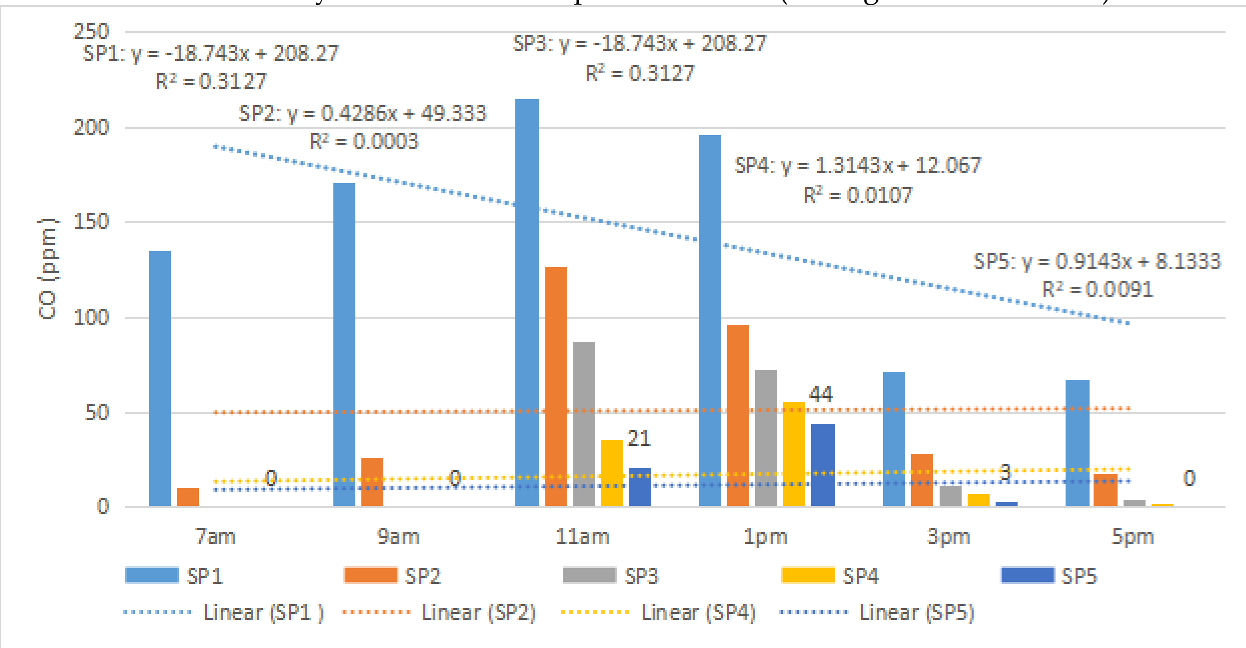


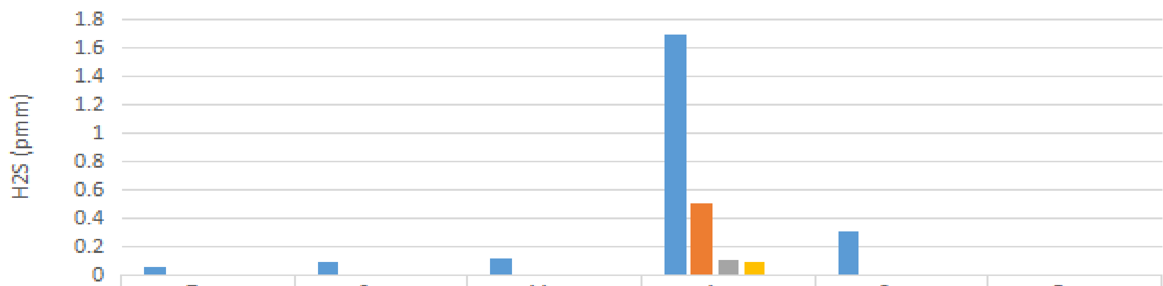
Figure 6: Spatial and temporal concentration of CO at Kunguni charcoal production area.
Source: Researcher Fieldwork, 2023

The result of Carbon monoxide (CO) over the day time at the charcoal production site depicts that CO was at its highest level (215 ppm) at 11am, followed by 196 ppm at 1pm, 171 ppm at 9am, 135 ppm at 7am, 72 ppm at 3pm, with the least (67 ppm) at 5pm having a trend line equation of y = -18.743x + 208.27 predicting a diurnal decrease in the concentration of CO while the R^2 is 0.3127 (31.27%) which is at relatively weak correlation between time of the day with ambient concentration of CO. At the second sampling point 50 meters away from the charcoal production site, CO was at its highest level (127 ppm) at 11am, 96 ppm at 1pm, 28 ppm at 3pm, 26 ppm at 3am, 18 ppm at 5pm and the least (10 ppm) at 7am having a trend line equation of y = 0.4286x + 49.333 predicting an insignificant decrease in the concentration of CO while the R^2 is 0.0003 (0.03%) depicting insignificant correlation between time of the day with ambient concentration of CO (See Figure 6 and Table 4).

Result at the third sampling point 100 meters away from the charcoal production area shows that CO was at its peak (88 ppm) at 11am, 73 ppm at 1pm, 12 ppm at 3pm, 4 ppm at 5pm and 0 ppm at 3pm and at 5pm having trend line equation of y = -18.743x + 208.27) predicts noticeable diurnal decrease in the concentration of CO with R^2 of 0.3127 (31.27%) given is a mild correlation between time of the day with ambient concentration of CO. The findings at the fourth sampling point shows that the highest (56 ppm) concentration of CO was recorded at 1pm, 36 ppm at 11pm, 7 at 9am while CO was not recorded in the morning by 7am and 9am. The trend line equation y = 1.3143x + 12.06 predicts an infinitesimal diurnal increase in the concentration of CO with R^2 value of 0.0107 (1.07%) depicting almost no correlation between time of the day with ambient concentration of CO. At the fifth sampling point, 200 meters away from the charcoal production site, CO was at its highest level (44 ppm) at 1pm, 21 ppm at 11am, 3 ppm at 3pm but CO was not recorded 7am, 9am and 5pm (See Figure 6 and Table 4).

Spatial and temporal concentration of H_2S at Kunguni charcoal production area

The concentration of H_2S in the air was more glaring at 1pm with 1.7 ppm at sampling point one (charcoal production site), 0.5 ppm 50 meters away from production site, 0.1 ppm 100 meters away from charcoal production site and 0.09 ppm 150 ppm away from the charcoal production site. H_2S was only observed at sampling point one the charcoal production area by 7am, 9am, 11am and 3pm with 0.05 ppm, 0.09 ppm, 0.12 ppm and 0.3 ppm respectively (Figure 7).

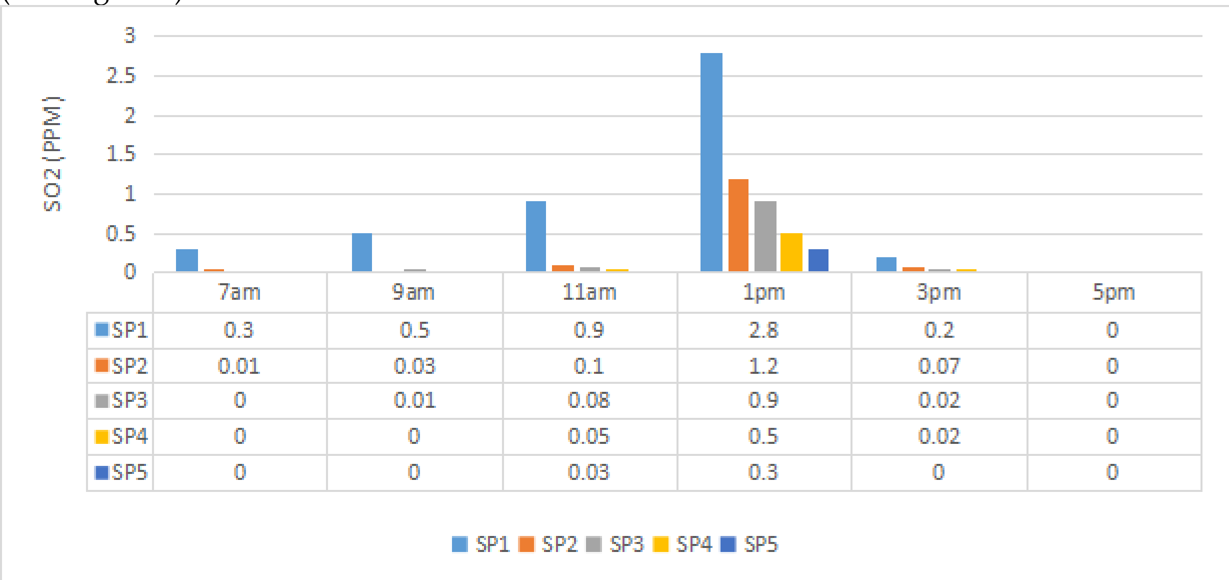


	7am	9am	11am	1pm	3pm	5pm
SP1	0.05	0.09	0.12	1.7	0.3	0
SP2	0	0	0	0.5	0	0
SP3	0	0	0	0.1	0	0
SP4	0	0	0	0.09	0	0
SP5	0	0	0	0	0	0

Figure 7: Spatial and temporal concentration of H_2S at Kunguni charcoal production area
Source: Researcher Fieldwork, 2023

Spatial and temporal concentration of SO_2 at Kunguni charcoal production area

At 7am, SO_2 (Sulphur dioxide) was only observed at the charcoal production site with 0.3 ppm and the second sampling point 50 meters from the production site with SO_2 value of 0.01 ppm. Observation of SO_2 at 9am depicts that SO_2 was 0.5 ppm, sample point two 50 meters away from charcoal production had 0.03 ppm and 0.01 ppm which is 100 meters away from production area. At 11am record of SO_2 shows that SO_2 was 0.9 ppm at the charcoal production site, 0.1 ppm at sample point two 50 meters away from charcoal production site, 0.08 ppm 100 meters away from the production site, 0.05 ppm 150 meters away from production area and 0.03 at 200 meters away from the charcoal production site (See Figure 8).



	7am	9am	11am	1pm	3pm	5pm
SP1	0.3	0.5	0.9	2.8	0.2	0
SP2	0.01	0.03	0.1	1.2	0.07	0
SP3	0	0.01	0.08	0.9	0.02	0
SP4	0	0	0.05	0.5	0.02	0
SP5	0	0	0.03	0.3	0	0

Figure 8: Spatial and temporal concentration of SO_2 at Kunguni charcoal production area
Source: Researcher Fieldwork, 2023

At 1pm, SO_2 was recorded at all sampling points with 2.8 ppm at the charcoal production site, 1.2 ppm at the second sampling points 50 meters away from the production site, 0.9 100 meters away from the production site, 0.5 ppm at 150 meters away from the charcoal production site while 0.3 ppm was observed at the fifth sampling site (200 meter away from the charcoal production site). Observations of SO_2 at 3pm depicts SO_2 to be 0.2 ppm at sampling point one (charcoal production site), 0.07 ppm 50 meters away from production site, 0.02 ppm 100 meters away from charcoal production site and 0.02 ppm 150 ppm away from the charcoal production site. SO_2 was not recorded at all the sampling points at 5pm (Figure 8).

Ambient Air Quality at charcoal production site at Kunguni community and Health Implication

In the charcoal production community of Kunguni shows that $PM_{2.5}$ concentration in all the sampling points were all above the permissible limit of 40 ug/m^3 except at sampling point five (200 meters away from the charcoal production site) with 22 ug/m^3 at 7am and at sampling point two (50 meters away from charcoal production site) with $PM_{2.5}$ value of 34 ug/m^3 within the permissible limit of 40 ug/m^3 prescribed F**MEnv/NESREA.** The findings is in agreement with the findings of Alfred, Bockarie, Eloise, Marais and MacKenzie (2020) who observed that the production charcoal in Africa is growing rapidly, driven by urbanization and lack of access to electricity. Charcoal production and its consumption release large quantities of trace gases and particles that impact air quality and climate. They assert that charcoal production in Africa contributes to surface concentrations of $PM_{2.5}$, particularly in site of charcoal production.

Table 4 shows that PM_{10} concentration from sampling points one and two were above the prescribed F**MEnv/NESREA** permissible limit of 150 ug/m^3 except at 5pm in the second sampling point with 50.5 ug/m^3. At all time of the day from sampling points, 3, 4 and 5, the PM_{10} concentration were within the permissible limits set by **FMEnv/NESREA** except at sampling point 3 (100 meters away from the charcoal production site) 9am with 168.7 ug/m^3 and 1pm with 192.2 ug/m^3 concentration which were above the set limit of F**MEnv/NESREA.** Generally, it was observed that for both, $PM_{2.5}$ and PM_{10} concentrations decreased away from the site of charcoal production. This is similarly with the opinion of Viney, Aneja and Peter (2012) were they observed that ambient concentration of PM_{10} generated from surface coal mining operations reduces with distance from mining site.

It was observed that CO concentration from sampling points one and two were at all time of the day was above the permissible limit of 4.36 ppm prescribed FMEnv/NESREA. At sampling point 3 and 4 CO at 7am and 9am was not recorded but the concentration was above the set limit of 4.36 ppm by FMEnv/NESREA (See Table 4). At 11am, 1pm, 3pm and 5pm. At sampling point 5, CO concentration exceeds the permissible limit at 11am and 1pm while the concentration at other times of the day well withing the permissible limit. Gabriel, Fae and Fábio (2012) observed that the production of charcoal impacts on air quality with the carbon monoxide reducing with distance from the production site with a value of 950 ppm to 907 ppm and the mass of gases reduced by 16.8%.

Table 4 shows that at 7am and 9am apart from sampling point one, from all other sampling points (2, 3, 4 and 5) SO_2 were within the permissible limit of 0.05ppm set by FMEnv/NESREA at sampling point 2, 3, 4 and 5. At 11am with the exception of sampling point five, the SO_2 concentration exceed the permissible limit of 0.05ppm at sampling points 1, 2, 3 and 4 while at all sampling points at 1pm the concentration exceeded the permissible limit. At 3pm, SO_2 concentration exceeded the permissible limit of 0.05ppm set by FMEnv/NESREA at sampling point 2 and 3 while SO_2 was not traced by 5pm at all the sampling points which is the peak of which the charcoal production doom are usually open. SO_2 was pronounced at the charcoal production site and at the late hour of the morning and in the afternoon**.** Shilpi, Gurdeep & Manish (2020) studied to know the current status of JCF concerning air quality. Ambient air quality monitoring with reference to particulate matter (PM_{10} and $PM_{2.5}$), SO_2, NO_2 and trace elements had been conducted in the coal mining area.

Table 4: Ambient Air Quality at charcoal production site at Kunguni Community and Health Implication

Profile of PM2.5						
Time	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	**FMEnv/NESREA**
7am	812.6*	151.2*	95.3*	71.2*	22	
9am	1015.2*	166.8*	128.4*	99.6*	64.9*	
11am	1257.2*	170.1*	94.3*	84*	68.3*	
1pm	1022.7*	202.5*	171.6*	129.8*	118.4*	40 ug/m^3
3pm	831.8*	133.7*	65.4*	93.8*	79.4*	
5pm	661.5*	34	29.5	79.5*	53.1*	
Profile of PM10						
Time	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	
7am	947.4*	176.8*	113.5	81.9	35.2	
9am	1234.9*	207.4*	168.7*	101.5	71.2	
11am	1338.6*	223.5*	102.8	93.1	72.2	150 ug/m^3
1pm	1370.5*	259.7*	192.2*	144.4	123.8	
3pm	917*	188.3*	76.6	101.2	83.9	
5pm	729.7*	50.5	35.1	82.8	64.4	
Profile of CO						
Time	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	
7am	135*	10*	0	0	0	
9am	171*	26*	0	0	0	
11am	215*	127*	88*	36*	21*	
1pm	196*	96*	73*	56*	44*	4.36 ppm
3pm	72*	28*	12*	7*	3	
5pm	67*	18*	4	1	0	
Profile of H_2S (ppm)						
Time	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	
7am	0.05	0	0	0	0	
9am	0.09	0	0	0	0	
11am	0.12	0	0	0	0	**5ppm**
1pm	1.7	0.5	0.1	0.09	0	
3pm	0.3	0	0	0	0	
5pm	0	0	0	0	0	
Profile of SO_2 (ppm)						
Time	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	
7am	0.3*	0.01	0	0	0	
9am	0.5*	0.03	0.01	0	0	
11am	0.9*	0.1*	0.08*	0.05*	0.03	0.05ppm
1pm	2.8*	1.2*	0.9*	0.5*	0.3*	
3pm	0.2*	0.07*	0.02	0.02	0	
5pm	0	0	0	0	0	

Source: Researcher Fieldwork and Analysis, 2023

From all the sampling points, H_2S concentration in the air was within the permissible limit of 5ppm set by the FMEnv/NESREA. This is in affirmation with Kļaviņa, Kārkliņa and Blumberga (2015) that ambient air pollution higher at point source emission with H_2S not dictated but with carbon monoxide (CO) and PM dictated in charcoal production site. Where $PM_{2.5}$ and PM_{10} were observed, CO was also pronounced in the charcoal production community of Kunguni. Zbigniew, Agnieszka, Iwona (2020) in their investigating also observed that there is contaminants correlation between particulate matter and CO. It is obviously clear that the major ambient air pollutants related to charcoal production in Kunguni community are $PM_{2.5}$, PM_{10}, CO and SO_2. Olujimi, Ana, Ogunseye and Fabunmi (2016) also were of the view $PM_{2.5}$, PM_{10}, CO and SO_2 were the major pollutants from charcoal production which occupationally exposed workers could be affected health wise by inhaling polluted air within the environment.

Test of air quality variation between sampling points at Kunguni Community charcoal production site

ANOVA tries to unveil if there is significant variation in the mean values of pollutants across sampling locations in the charcoal production site at Kunguni community. The Post hoc test explains where variations lie. This is an "after the fact test" specifically it was carried out after a significant ANOVA result.

Test of $PM_{2.5}$ air quality variation between sampling points at Kunguni Community charcoal production site

Ho: 1. *There is no significant variation in the $PM_{2.5}$ concentration between sampling points at Kunguni Community charcoal production site*

Table 5 shows that there is a notable variation in PM $_{2.5}$ levels at predetermined intervals of 50m throughout the research region. Specifically, the p-value (ANOVA) is less than .001 and is below the level of significance of interest (0.05) which proves that there is a statistically significant difference between the groups, thereby rejecting the null hypothesis. However, ANOVA couldn't pinpoint the precise locations of the observed disparities in pollutant mean values throughout the study area's sampled points. The Post Hoc test identified the locations of the differences. The results demonstrate that there is a statistically significant difference between the PM $_{2.5}$ concentrations at sample locations 1 (charcoal production site) and sample location 2 (50 meters away from charcoal production site) with p =0.001. When comparing sampling points 1 (charcoal production location) and sampling point 3 (100 meters away from charcoal production site) depicts a statistically significant difference (p =0.001).

Table 5: Test of $PM_{2.5}$ air quality variation between sampling points at Kunguni Community charcoal production site

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2970597.824	4	742649.456	83.865	.000
Within Groups	177105.96	20	8855.298		
Total	3147703.784	24			

Particulate Matter 2.5 Post Hoc Test

Test	p-value	Significant?	Measure of Association (Eta squared)
Station 1 vs Station 2	<.001	Yes	0.944
Station 2 vs Station 3	.892	No	
Station 2 vs Station 4	.772	No	
Station 2 vs Station 5	.591	No	
Station 3 vs Station 1	<.001	Yes	
Station 3 vs Station 4	.999	No	
Station 3 vs Station 5	.978	No	
Station 4 vs Station 1	<.001	Yes	
Station 4 vs Station 5	.998	No	
Station 5 vs Station 1	<.001	Yes	

Stations	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	***Total***
Mean	970.87	164.86	111	95.68	77.26	283.93
Std. Deviation	201.22	25.52	40.55	21.90	31.78	362.15

Source: Researcher Fieldwork, 2023

There is a statistically significant difference between sampling point 4 (150 meters away from the charcoal production site) and sampling point 1 (charcoal production site) with p=0.001). Between sampling point 5 (200 meters away from the charcoal production site and sample point 1 (charcoal production site) there also exists a significance difference with p=0.001), but there is no difference between sampling points 3 and 2 with p-value = 0.892), sampling points 2 and 4 with p-value =0 .772, sampling points 2 and 5 with p-value = 0.591, sampling points 3 and 5 with p-value = 0.978, and sampling points 4 and 5 with p-value =0.998. The measure of association (Eta squared) of $PM_{2.5}$ (n^2 =0.944) shows a statistically significant variation between the stations used for the investigation (eta values closer to one explain a higher proportion of variances among samples) (Table 5).

Test of PM_{10} air quality variation between sampling points at Kunguni Community charcoal production site

Ho: 2. *There is no significant variation in the PM_{10} concentration between sampling points at Kunguni Community charcoal production site*

Table 6, shows that PM_{10} concentrations vary significantly at regular intervals of 50 meters over the study area. There exist statistically significant difference between the groups because the p-value (ANOVA) 0.001 is less than level of significance of interest (0.05). The variance was traced back to its original data source with the use of the Post Hoc test.

The Post Hoc results show that the PM_{10} concentrations in the charcoal production site (Sample location 1) and sample location 2 (50 meters away from charcoal production site) are statistically different with p-value of 0.001. There is a statistically significant difference (p =0.001) between points 1 (the charcoal production site) and 3 (100 meters away from the charcoal production site) when compared. While there is a statistically significant difference between sampling points 4 (150 meters away from the charcoal production site) and 1 (the charcoal production site) with p-value =0.001) and points 5 (200 meters away from the charcoal production site) and at sampling point 1 (the charcoal production site) with p-value =0.001. No difference exists between the means of sampling points (150 meters away from the charcoal production site) and sampling point 2 (50 meters away from the charcoal production site) with p-value =0.867. Sampling point 2 (50 meters away from the charcoal production site) and 4 (150 meters away from the charcoal production site) with p-value =0.712, sampling point 2 and 5 with p-value =0.475, sampling points 3 and 5 with p-value =0.954, and points 4 and 5 with p-value =0.994) shows no significance difference. The measure of association (Eta squared) depict a statistically significant variance in PM 10 (n^2 =0.940) between the study points in the study (eta values closer to one explains a higher proportion of variances among samples).

Table 6: Test of PM_{10} air quality variation between sampling points at Kunguni Community charcoal production site

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4177998.261	4	1044500	77.911	.000
Within Groups	268127.514	20	13406.38		
Total	4446125.775	24			

Particulate Matter 10 Post Hoc Test

Test	p-value	Significant?	Measure of Association (Eta squared)
Station 1 vs Station 2	<.001	Yes	
Station 2 vs Station 3	.867	No	
Station 2 vs Station 4	.712	No	
Station 2 vs Station 5	.475	No	
Station 3 vs Station 1	<.001	Yes	
Station 3 vs Station 4	.998	No	.940
Station 3 vs Station 5	.954	No	
Station 4 vs Station 1	<.001	Yes	
Station 4 vs Station 5	.994	No	
Station 5 vs Station 1	<.001	Yes	

Stations	***SP1***	***SP2***	***SP3***	***SP4***	***SP5***	***Total***
Mean	1142.95	197.36	126.61	104.42	75.31	329.33
Std. Deviation	244.39	52.85	54.36	23.73	31.58	430.41

Source: Researcher Fieldwork, 2023

3.3.3: Test of charcoal production site Carbon Monoxide air quality variation between sampling points at Kunguni Community

Ho: 3. *There is no significant variation in the CO concentration between sampling points at Kunguni Community charcoal production site*

As shown in Table 7, the CO_2 levels in the study area vary significantly at regular intervals of 50m. Findings conclude that there is a significant variation in the CO concentration between sampling points at Kunguni Community charcoal production site with p-value (ANOVA) is less than 0.001 and is lower than the level of significance of interest (0.05). Understanding where the differences came from is made easier by the Post Hoc test. The Post Hoc results shows that there is a statistically significant variation in CO_2 levels between sites 1 (charcoal production area) and 2 (50 meters away from the charcoal production area) with p-value =0.009. There is also a statistically significant distinction between point 1 (charcoal production site) and sampling point 3 (100 meters from charcoal production site) with p value =0.001. Sampling point 4 and 1 differ significantly with p value =0.001), as do those of points 5 and 1 with p value=0.001), but the means of sampling points 2 and 4 do not differ significantly with p value =0.907), nor do those of sampling points 2 and 5 with p value =0.620), nor do those of points 3 and 5 with p value =0.929, as well as that of sampling points 4 and 5 with p value =0.999. There is a statistically significant variation in the CO_2 (n^2 =0.665) between the sampling points of the study.

Table 7: Test of Carbon Monoxide air quality variation between sampling points at Kunguni Community charcoal production site

<table>
<tr><td colspan="2"></td><td>Sum of Squares</td><td>df</td><td>Mean Square</td><td>F</td><td>Sig.</td></tr>
<tr><td colspan="2">Between Groups</td><td>69141.76</td><td>4</td><td>17285.44</td><td>9.916</td><td>.000</td></tr>
<tr><td colspan="2">Within Groups</td><td>34865.2</td><td>20</td><td>1743.26</td><td></td><td></td></tr>
<tr><td colspan="2">Total</td><td>104006.96</td><td>24</td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Carbon Monoxide Post Hoc Test</td></tr>
<tr><td colspan="2">Test</td><td>p-value</td><td>Significant?</td><td colspan="3">Measure of Association (Eta squared)</td></tr>
<tr><td colspan="2">Station 1 vs Station 2</td><td>.009</td><td>Yes</td><td colspan="3" rowspan="10">.665</td></tr>
<tr><td colspan="2">Station 2 vs Station 3</td><td>.907</td><td>No</td></tr>
<tr><td colspan="2">Station 2 vs Station 4</td><td>.620</td><td>No</td></tr>
<tr><td colspan="2">Station 2 vs Station 5</td><td>.480</td><td>No</td></tr>
<tr><td colspan="2">Station 3 vs Station 1</td><td><.001</td><td>Yes</td></tr>
<tr><td colspan="2">Station 3 vs Station 4</td><td>.979</td><td>No</td></tr>
<tr><td colspan="2">Station 3 vs Station 5</td><td>.929</td><td>No</td></tr>
<tr><td colspan="2">Station 4 vs Station 1</td><td><.001</td><td>Yes</td></tr>
<tr><td colspan="2">Station 4 vs Station 5</td><td>.999</td><td>No</td></tr>
<tr><td colspan="2">Station 5 vs Station 1</td><td><.001</td><td>Yes</td></tr>
<tr><td>Stations</td><td>SP1</td><td>SP2</td><td>SP3</td><td>SP4</td><td>SP5</td><td>Total</td></tr>
<tr><td>Mean</td><td>157.30</td><td>57.40</td><td>34.60</td><td>19.80</td><td>13.60</td><td>56.54</td></tr>
<tr><td>Std. Deviation</td><td>57.49</td><td>51.07</td><td>42.52</td><td>25.10</td><td>19.11</td><td>65.83</td></tr>
</table>

Source: Researcher Fieldwork, 2023

$PM_{2.5}$ is more travel away from charcoal production site at all the sampling points at all time of the day making their ways into deeper parts of the lung, while PM_{10} is more likely to deposit on the surfaces of the larger airways of the upper region of the lung. This increases the vulnerability charcoal producer or people living at vicinity of Kunguni community, Kwali Area Council because these particles when deposited on the lung surface can induce tissue damage, and lung inflammation. PM_{10} particles are small enough to pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects particularly within 50 meters radius of the charcoal production site. The $PM_{2.5}$ smaller in size move faster and could traced in at alarming rate at all the sampling points at all time of the day. Getting in deep into the lungs and into the bloodstream could be disaster to human health. Numerous studies have showed associations between exposure to particles and increased hospital admissions as well as death from heart or lung diseases.

The short-term exposure to $PM_{2.5}$ and PM_{10} appears to exacerbate pre-existing diseases while long-term exposure most likely causes disease and increases the rate of progression. Some of the short-term exposure (hours to days) can lead to irritated eyes, nose and throat, worsening asthma and lung diseases such as chronic bronchitis, heart attacks and arrhythmias (irregular heart beat) in people with heart disease, increases in hospital admissions and premature death due to diseases of the respiratory and cardiovascular systems.

The long-term exposure which last for over five years reduced lung function, development of cardiovascular and respiratory diseases, increased rate of disease progression and reduction in life expectancy. All these are threatening health status of charcoal production and inhabitants of host communities. This is in agreement with the findings of Jialong, *et. al.,* (2023).

The concentration of carbon monoxide at all times at sampling points 1 and two and 11 am, 1pm sampling 3, 4 and 5 as well as at sampling point 3 and four at 3pm were above the set limit at the charcoal production site Kunguni community, Kwali Area Council. The implication is that, the concentration of CO can dramatically reduce hemoglobin's ability to transport oxygen. Other effects exposure of CO at the charcoal production site at Kunguni community, Kwali Area Council includes headache, nausea, rapid breathing, weakness, exhaustion, dizziness, and confusion when these are prolong as also observed by Tze-Ming, Ware, Janaki and Scott (2007). Tze-Ming, Ware, Janaki and Scott (2007) also asserted that prolonged exposure to CO for days and months may have subtle effects on the brain. Daily exposure, leading to symptoms including headache and malaise are often reported with periods of recovery to normality occurring when exposure stops.

SO_2 exceeds the permissible limit of NESREA at all study time except 5pm at charcoal production area (sampling point 1). At sampling point 2 it exceed the lit at 11am, 1pm and 3pm. At Sampling pint 3 and 4 it exceed the limit at 11am and 1pm while at sampling point 5 it exceeded at 1 pm. At areas where SO_2 is pronounced above set limits, SO_2 can cause respiratory problems such as bronchitis, and can irritate inhabitants nose, throat and lungs. It may cause coughing, wheezing, phlegm and asthma attacks. The effects SO_2 are worse among infants and the elderly is the community. This in view of the findings of Tze-Ming, Ware, Janaki and Scott (2007) who affirmed that sulfur dioxide (SO_2) contributes to respiratory symptoms in both healthy patients and those with underlying pulmonary disease, the observed that human exposure to SO_2 exposure causes changes in airway physiology, including increased airways resistance. Both acute and chronic exposures to carbon monoxide are associated with increased risk for adverse cardiopulmonary events, including death. In addition, Jialong *et. al.,* (2023) a number of studies examining the effects of ambient level exposure to NO_2, SO_2, and CO have failed to find associations with adverse health outcomes.

Jialong, *et. al.,* (2023) and Eniola and Odebode (2018b) were of the view also that $PM_{2.5}$, PM_{10} and SO_2 are associated with increased prevalence of pain/discomfort and anxiety/depression. The findings of Jialong, *et. al.,* (2023) depicts that health status of infants and older Chinese adults was not only associated with demographic, socioeconomic, and health-related factors, but also negatively correlated with air pollution, especially through increased pain/discomfort and anxiety/depression it is a pointer to the implications of the observations of this study meaning that the infants and the aged health will seriously be jeopardize.

CONCLUSION AND RECOMMENDATIONS

This study at the Kunguni community, Kwali Area Council of FCT, Nigeria concludes that NO_2 and NH_3 were not traced in the charcoal producing area meaning charcoal production does not emits NO_2 and NH_3. H_2S was recorded in the charcoal production area but within the permissible limits of FMEnv/NESREA. It was concluded that SO_2, CO, $PM_{2.5}$ and PM_{10} at the charcoal producing community of Kunguni in Kwali Area Council largely conclude that the values obtain from most of the sampling points exceeds the permissible limits sets by FMEnv/NESREA. The study conclude that, the charcoal producer or people living at vicinity of Kunguni community, Kwali Area Council are vulnerable to inhaling pollutants (SO_2, CO, $PM_{2.5}$ and PM_{10}) that when deposited on the lung surface can induce tissue damage, lung inflammation, irritated eyes, nose, throat, worsening asthma and lung diseases such as chronic bronchitis, heart attacks and irregular heart beat in people with heart disease, increases in hospital admissions and premature death due to diseases of the respiratory and cardiovascular systems.

Based on the research findings, the following recommendations may be considered appropriate;

i. Pollution prevention strategies as well as public awareness might be a sensible and valuable approach to decrease hazardous air emissions around charcoal kilns areas. Regular contact could prompt certain chronic health problems if the worker does not utilize respiratory protection equipment, which is fairly inconsistent.

ii. There is need for the government of Nigeria to regulate the charcoal production industries and environmentally friendly technology such as fuel efficient stoves should be provided by the government at affordable prices to the masses as alternative to the unsustainable production and utilization of charcoal in the Area Council.

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