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EFFECT OF METEOROLOGICAL PARAMETERS ON THE DISPERSION OF VEHICULAR EMISSION IN SOME SELECTED AREAS IN KANO STATE -NIGERIA

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ABSTRACT
In this research work, the results of vehicular emissions in some selected areas in Kano State – Nigeria were investigated. The investigation was meant to detect the presence of CO, $PM_{2.5}$ and PM_{10} using a portable gas sensor (Model- 00014d), air quality detector (Model- 00684c) and particulate meter (Model-00148de). Three areas which include Kofar Wambai (SA_1), Kantin Kwari (SA_2), and Sabon Gari Market (SA_3) were considered with nine sampling points (SP_1 to SP_9) in each area placed 5.0m away from the edge of the road in downwind direction. The meteorological parameters used were Ambient Temperature, Wind Direction, Wind Speed and Relative Humidity obtained from Malam Aminu International Airport, Kano. The results of the highest level obtained for the air pollution indicator for CO were; 40ppm, at SP_5 for day 1, 47ppm and 41ppm at SP_5 for days 2 and 3 respectively. The concentration of $PM_{2.5}$ was highest at SP_2 with a value of 184 $\mu g/m^3$ on day 3 and the highest concentration of PM_{10} was observed to be 169 $\mu g/m^3$ at SP_2 on day 1. However, the three monitored air pollutants when compared with AQI level (Air quality index) were in the range of poor to moderate and moderate to poor for CO at SP_5, poor to very poor for $PM_{2.5}$ at all locations of the sample areas and very poor to poor for PM_{10} at SP_2. It was generally observed from the result that $PM_{2.5}$ was found to be the most abundant air pollutant in all three areas. Moreover, the mean association of $PM_{2.5}$ levels and selected meteorological parameters during the period of the study is established. Pearson's coefficient of correlation was applied to study the association between $PM_{2.5}$ and meteorological variables. A statistical significant positive association was observed between $PM_{2.5}$ with temperature. There was a negative and statistical correlation between $PM_{2.5}$ with wind speed, wind direction and relative humidity, which exhibited a washing effect evidenced by its negative correlation with fine particle fractions. The study, clearly points out that wind and temperature are the most important meteorological parameters influencing the behaviour of air pollutants in Kano City.
Keywords: Air pollution, Air quality index, Meteorological parameters, Vehicular emission

INTRODUCTION

The concept of environment is as old as the concept of nature itself. It is a composite term referring to conditions in which organisms consisting of air, water, food, sunlight etc., thrive and become living sources of life for all the living and non-living beings including plant life. The term also includes atmospheric temperature, wind and velocity. The Royal Commission on Environmental Pollution in the U.K. in its third report gave the following definition of the term Pollution: 'The introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity or interference with This factor has been largely responsible for the generation of synthetic and non-biodegradable legitimate uses of the environment" (Appannagari, 2017).

Modern thinkers consider that the growth of the population is the root cause of many human problems. This observation also applies to environmental degradation. An increase in the population will have a multiplier effect requiring proportionate increase in all requirements necessary for the existence of human beings. The nature of productive technology in recent years is closely related to the environmental crisis. Commoner maintains that sweeping transformations of productive technology since World War II productive technologies with intense impacts on the environment have displaced less destructive ones.

substances such as plastics, chemical nitrogen fertilizers and synthetic detergents, synthetic fibres. The rapid rate of industrialization resulted in a rapid rate of exploitation of natural resources and increased industrial output. Both the components of industrial development e.g. exploitation of natural resources (Appannagari, 2017)

Some of the major combustion-generated compounds, includes the oxides of nitrogen, sulfur dioxide, carbon monoxide, unburned hydrocarbons, particulate matter, Nitric oxide (NO) and nitrogen dioxide ($N0_2$) are the two most important Nitrogen Oxide air pollutants. They are frequently lumped together under the designation *NOx* although analytical techniques can distinguish clearly between them, of the two, $N0_2$ is the more toxic and irritating compound. Sulfur dioxide ($S0_2$) is formed from the oxidation of sulfur contained in fuel as well as from certain industrial processes that utilize sulfur-containing compounds. Organic air pollutants are sometimes divided according to volatile organic compounds (VOCs) and particulate organic compounds (POCs), although some species will be distributed between the gaseous and particulate phases. The emission of unburned or partially burned fuel from combustion processes and the escape of organic vapours from industrial operations are the major anthropogenic sources of organic air pollutants. (Flagan and Seinfeld, 1988).

Kano is one of the megacities in West Africa. It is referred to as the centre of commerce due to its long flourishing marketing activities which dominated the economic activities of the indigenes. It is one of the oldest but growing and densely populated cities in Nigeria. The rapid urban growth of the Kano metropolis is attributed to the migration of people from rural areas, either for labour or commercial activities, being the centre of industry, commerce and education (Garba and Yunusa, 2016) and this result to the situation of increased pollution from mobile transportation sources thus resulting in high congestion on Kano city roads and an increase in the concentration of pollutants in the air, consequently, increasing health risk to the human population. In this research work, the results of vehicular emissions in some selected areas in Kano State – Nigeria were investigated. The investigation was meant to detect the presence of CO, $PM_{2.5}$ and PM_{10} using a portable gas sensor (Model- 00014d), air quality detector (Model-00684c) and particulate meter (Model-00148de).

TRAFFIC EMISSIONS IN NIGERIAN CITIES

In Nigeria much attention is given to general industrial pollution and pollution in oil industries, with little reference to damage of pollution caused by mobile transportation sources of air pollution (Okunola et al. 2012). The situation of increased pollution from mobile transportation sources is on the increase in per capital vehicle ownership, thus resulting in high congestion on Nigerian city roads and an increase in the concentration of pollutants in the air, consequently, increasing health risk to the human population. Studies conducted in Kaduna and Abuja cities show higher values of CO2 concentration in heavily congested areas: 1840ppm for Sambo Kaduna, 1780ppm for Stadium round-about, Kaduna, and 1530ppm for A.Y.A, Abuja and 1160ppm for Asokoro Abuja, Akpan and Ndoke, (1999). Similar work by Ndoke and Jimo, (2000) at Minna, a city in Nigeria shows the maximum value of 5,000ppm for CO2 in congested areas, which was still lower than the WHO stipulated maximum value of 20,000ppm. The maximum value for CO emission obtained was 15ppm still lower than the base line of 48ppm stipulated by WHO and 20ppm stipulated by the Federal Environmental protection Agency of Nigeria (FEPA). The reason for this low emission concentration in Minna is due to low traffic and industrial activities in the city (Abam and Unachukwu, 2009). Kano is one of the megacities in West Africa. It is referred to as the centre of commerce due to its long flourishing marketing activities which dominated the economic activities of the indigenes. It is one of the oldest but growing and densely populated cities in Nigeria. The rapid urban growth of the Kano metropolis is attributed to the migration of people from rural areas, either for labour or commercial activities, being the centre of industry, commerce and education (Garba and Yunusa, 2016).

Figure 1: Traffic situation in Sabon Gari, Kano State – Nigeria.

HEALTH EFFECTS OF AIR POLLUTION

Sporadic air pollution events, like the historic London fog in 1952 and several short and long term epidemiological studies investigated the effects of air quality changes on human health. A constant finding is that air pollutants contribute to increased mortality and hospital admissions (Brunekreef and Holgate, 2002). Epidemiological and animal model data indicate that the primarily affected systems are the cardiovascular and the respiratory system. However, the function of several other organs can be also influenced (Cohen et al., 2005; Huang and Ghio, 2006; Kunzli and Tager, 2005; Sharma and Agrawal, 2005). Numerous studies describe that all types of air pollution, at high concentrations, can affect the airways. Nevertheless, similar effects are also observed with long-term exposure to lower pollutant concentrations. Symptoms such as nose and throat irritation, followed by bronchoconstriction and dyspnoea, especially in asthmatic individuals, are usually experienced after exposure to increased levels of sulphur dioxide (Balmes et al., 1987), Nitrogen Oxides (Kagawa, 1985), and certain heavy metals such as arsenic, nickel or vanadium. In addition particulate matter that penetrates the alveolar epithelium (Ghio and Huang, 2004) and ozone initiate lung inflammation (Uysal and Schapira, 2003). In patients with lung lesions or lung diseases, pollutant-initiated inflammation will worsen their condition. Finally, chronic exposure to ozone and certain heavy metals reduces lung function (Rastogi et al., 1991; Tager et al., 2005), while the latter is also responsible for asthma, emphysema, and even lung cancer (Kuo et al., 2006; Nawrot et al., 2006). Emphysema-like lesions have also been observed in mice exposed to nitrogen dioxide (Wegmann et al., 2005).

LITERATURE REVIEW

Some of the literature reviewed for this research include the following:

Giri, Murthy, and Adhikary, (2008) carried out a study on "the influence of Meteorological conditions on PM_{10} concentration in Kathmandu Valley" in their results, Pearson's coefficient of correlation was applied to study the association between PM_{10} and meteorological variables. The atmospheric pressure, wind velocity and humidity were found to be significant factors compared to other influencing PM_{10}. An increase in rainfall and humidity has a negative correlation with the average PM_{10} concentration in Kathmandu Valley. The study also infers that the wind speed and atmospheric pressure include an increment of average PM_{10} concentration in Kathmandu Valley.

Radaideh (2017) researched the topic "Effect of meteorological variables on Air pollutants variation in arid climate" Acquired results indicate most of the observed key air pollutants increase with an increase in relative humidity, except NO_2, which experiences a decrease in concentrations simultaneous with increasing relative humidity. This survey study suggests that concentrations of TVOC concentrations increase by 201%, CO by 15.2%, SO_2 by 21.6% and ozone by 16% as a direct contribution to relative humidity change. While NO_2 experiences a decrease of 53.4% as a result of an increase in relative humidity. Ozone exhibits only slightly spatial variation due to sudden changes in meteorological variables.

Shenfeld's (1970) "Meteorological aspects of air pollution control" explained that, Meteorological factors have an important effect on the amount of pollution in the atmosphere. Temperature and solar radiation affect the quantities of pollutants emitted by their influence on the amount of space heating required. Sunshine is required in the photochemical production of oxidants forming smog.

The wind velocity, turbulence and stability affect the transport, dilation and dispersion of the pollutants. The rain-fall as a scavenging effect in washing out ("rainout") particles in the atmosphere.

THEORETICAL BACKGROUND

These equations were used in the computation of plume rise and dispersion of the air pollutants considered.

The Plume Rise Equation as proposed by Holland (1953) used to determine ΔH

$$\Delta H = \left(\frac{v_s d}{u}\right)\left(1.5 + \frac{0.00268 pd(T_S - T_a)}{T_S}\right) \quad (1)$$

Where ΔH is the plume rise (m), v, the gas exit velocity (m/sec), d the diameter of the top of the stack (m), p the atmospheric pressure (mb), u the wind speed at the top of the stack(m/sec), and T_a, T_s the temperatures of the air and the gas at exit respectively (K).

The Dispersion Formula

$$C = \left(\frac{Q}{2\pi u \sigma_y \sigma_z}\right)\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_Z}\right)^2\right] + \exp[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2]\right\}\left\{\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\right\} \quad (2)$$

Where C is the concentration at the point of impingement (gm/m^3), Q is the rate of emission (gmlsec), z is the height of receptor (m), H is the effective stack height (height of stack h + plume rise ΔH), u the wind speed as for Eq. (I), and y the distance from the centre line of the plume (m). σ_y ,σ_z the standard deviations of the plume concentration distributions in the horizontal and vertical, respectively, (m) are functions of the stability of the atmosphere and the distance from the source, x. (Pasquill, 1962 : Gifford, 196).

MATERIALS AND METHOD

The equipment used in conducting the research work are: Gas Sensor (Model: 00014d), Air Quality Detector (Model: 00684c), Particulate Meter (Model: 00148de)

THE STUDY AREA

The study area is Kano city, the locations considered for this project are: SA_1, SA_2 and SA_3. Kano has a population of 4,103,000 in 2021 with an increased rate of 2.6% from 2020 to 2021.and is influenced by the local steppe climate. During the year, there is little rainfall. This climate is considered to be BSH the temperature averages 26.3 ^{0}C (79.4 ^{0}F) precipitation have is about 674mm (26.5inch) per year. The concentration of CO, $PM_{2.5}$, and PM_{10} were found in three different places; SA_1, SA_2 and SA_3. SA_2 is located in Fagge local government on the latitude 12.007896 and longitude 8.534621. The second place is SA_1 located at Fagge local government area on latitude 12.006526 and longitude 8.524407. SA_3 is in Nassarawa local government, it has a latitude of 12.023983 and a longitude of 8.536398. These places have emerged as growing commercial centres of Kano city. The areas with heavy vehicular traffic and large commercial buildings characterized these places. The meteorological parameters were found at Malam Aminu Kano International Airport which is required to establish the relationship between the pollutants and meteorological parameters. The impact of vehicular emission on ambient air quality was monitored in selected areas in Kano. The areas are marked SA_1, SA_2 and SA_3. Each of these areas has different sample points of which CO, $PM_{2.5}$, and PM_{10} concentrations were monitored. Other parameters monitored include: ambient temperature, wind directions and wind speed. The three areas SA_1, SA_2 and SA_3 have sample points selected for monitoring in the priority of high population density and traffic congestion as shown in table 1.

Table 1: Sample ID Code.

S/N	Sample areas (SA)	Sample points	Section
1		SP_1	Kofar Wambai Police Station
	SA_1 (Kofar Wambai)	SP_2	I. B. B. Road
		SP_3	Masallacin Idi
2		SP_4	Kofar Abbale
	SA_2 (Kantin Kwari)	SP_5	Ibrahim Tayo Road
		SP_6	I. B. B. Road
3		SP_7	Yan Kura Junction
	SA_3 (Sabon Gari)	SP_8	Bata Junction
		SP_9	Abubakar Rimi Market

The monitoring instruments were held some meters from the road on the busy streets in a downwind direction. The areas SA_1, SA_2 and SA_3, have emerged as growing commercial centres of Kano city. The areas with heavy vehicular traffic and large commercial buildings characterized these places. Ambient air and other emissions concentration observed for 3 days regularly are CO, $PM_{2.5}$, and PM10.

Other parameters obtained from Malam Aminu Kano International Airport which are required to establish the relationship between the pollutants and meteorological parameters are relative humidity, wind direction, ambient temperature and wind velocity.

METHOD OF INVESTIGATION

In all the places, the concentrations of CO, $PM_{2.5}$ and PM_{10} were determined by standard method on daily basis. A portable gas sensor model (00014d), air quality detector model (00684c) and particulate meter model (000148de) were obtained from the ministry of environment and pollution control laboratory Farm Center, Kano. And also the analysis was done there. In this study, we consider the average daily CO, $PM_{2.5}$ and PM_{10} concentration recorded in three places which include Kofar Wambai, Kantin Kwari and Sabon Gari market. The meteorological data obtained from Malam Aminu Kano International Airport was used to consider the weather information of the corresponding period. A total of 27 observations were considered for the analysis. To get a better representation of the CO, $PM_{2.5}$ and PM_{10} concentration in the city and also to understand the effect of meteorological parameters on the data obtained, the data that were available are considered.

RESULTS AND DISCUSSION

In this research work, three pollutants were considered. These include CO, $PM_{2.5}$, and PM_{10}. The air quality index (AQI) was used to access the concentrations of the pollutants considered. It is a rating scale for outdoor air. The lower the AQI value the better the air quality. In Nigeria, there is neither a legislative framework nor a set standard to monitor emissions from a mobile source. The regulatory framework put in place by the government through FEPA is limited to emissions generated through the stationary source. In the absence of these standards, the data in this research work is compared with the (USEPA, 2006) ambient air quality standards.

Table 2: Air quality data for day 1

S/N	Sample point	CO ppm	$PM_{2.5}$ $\mu g/m^3$	PM_{10} $\mu g/m^3$	Temp. (^0C)	W/speed (m/s)	W/direction (degrees)	R/humidity (%)
1	SP_1	10	34	33	31.8	8	100	23
2	SP_2	16	183	169	32.8	11	100	25
3	SP_3	14	51	53	32.4	12	110	23
4	SP_4	40	71	75	34.8	10	60	26
5	SP_5	40	27	30	35	11	60	25
6	SP_6	17	23	25	36	11	120	24
7	SP_7	12	168	71	36.9	10	100	24
8	SP_8	15	72	37	36.5	7	110	25
9	SP_9	13	141	89	35.6	8	100	26

Table 3: Air quality data for day 2

S/N	Sample point	CO ppm	$PM_{2.5}$ $\mu g/m^3$	PM_{10} $\mu g/m^3$	Temp. (^0C)	W/speed (m/s)	W/direction (degrees)	R/humidity (%)
1	SP_1	11	36	35	35	8	90	22
2	SP_2	20	180	130	33.7	6	90	28
3	SP_3	17	67	59	33	11	100	25
4	SP_4	40	75	85	32.7	9	90	25
5	SP_5	47	25	31	32	10	90	31
6	SP_6	30	19	30	34	7	90	28
7	SP_7	30	150	80	30.5	8	100	29
8	SP_8	15	102	31	31.2	9	100	21
9	SP_9	20	151	97	33	9	100	22

The results of the monitored air quality and metrological parameters at nine sampling points (SP_1 to SP_9) in areas SA_1, SA_2 and SA_3 are tabulated in Tables 2, 3 and 4. The average values of CO were found to be 18.55 ppm, 25.55 ppm and 20.77 ppm for days 1, 2 and 3 respectively which were below the permissible limit of 40ppm USEPA ambient air quality standards (US EPA, 2006). The concentration of CO across the study areas at the nine locations as seen in Tables 2, 3 and 4 revealed the highest value at SP_5 due to traffic congestion and traffic intersection, where the long waiting time for vehicles is observed. Similarly, the average concentration of $PM_{2.5}$ was found to be 85.55 $\mu g/m^3$, 89.44 $\mu g/m^3$, and 83.88 $\mu g/m^3$ on days 1, 2, and day 3 respectively as shown in Table 2, 3 and 4.

The highest value was observed at SP_2. This could be a result of the high rate of combustion particles and another organic compounds. However, the highest concentration of PM_{10} was observed at SP_2 for all the three day as shown in tables 2, 3 and 4. This could be associated with the characteristics of the area being a place for regular movement of people and goods as well as a market trading in all sorts of substances. The gaseous emission generated from these substances could be responsible for the high PM_{10}.

Table 4: Air quality data for day 3

S/N	Sample point	CO ppm	$PM_{2.5}$ $\mu g/m^3$	PM_{10} $\mu g/m^3$	Temp. (^0C)	W/speed (m/s)	W/direction (degrees)	R/humidity (%)
1	S_1	10	30	35	33	11	60	28
2	S_2	24	184	130	31.2	9	100	20
3	S_3	14	51	59	28.7	14	110	29
4	S_4	39	70	85	28.6	13	90	21
5	S_5	41	27	31	24.5	9	80	20
6	S_6	20	25	30	26.7	13	70	18
7	S_7	10	168	80	29.4	13	110	14
8	S_8	18	70	31	31	10	70	13
9	S_9	11	130	97	30.8	11	80	11

The particulate matter $PM_{2.5}$ was found to be very high in all locations of the sample areas, SA_1 – SA_3. Comparing $PM_{2.5}$ with AQI levels, the quality of ambient air in some areas was very poor. The concentration of $PM_{2.5}$ was in the range of 19 $\mu g/m^3$ – 184 $\mu g/m^3$ against the USEPA ambient air quality standard of 35 $\mu g/m^3$ in some locations. The high value of $PM_{2.5}$ is dependent on traffic volume, length of delays and meteorological conditions (especially wind direction and speed). Population rate, and the increased rate of a combustion engine, also contribute to a high concentration of $PM_{2.5}$.

Table 5: Average concentration of some pollutants compared with USEPA standards

S/N	Parameters	Kofar wambai (SA_1)	Kantin kwari (SA_3)	Sabon gari (SA_2)	USEPA LIMIT (USEPA, 2013)
1	CO (ppm)	15.11	33.77	16	40
2	$PM_{2.5}$ ($\mu g/m^3$)	90.66	40.22	128	35
3	PM_{10} ($\mu g/m^3$)	82.44	44.88	65.88	150

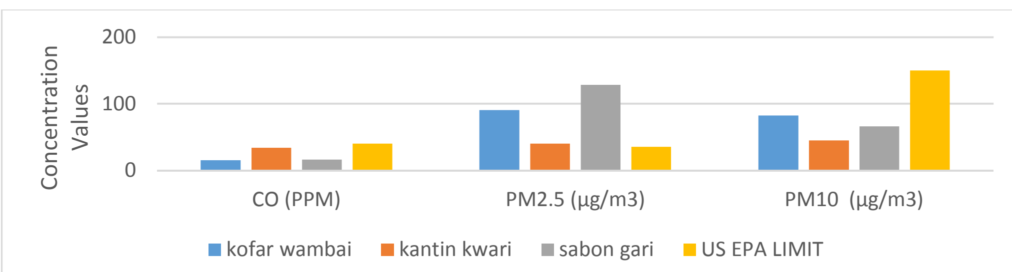

Figure 2: Comparison between research values of CO, PM2.5 and PM10 and USEPA Standard limit

The average values of CO, $PM_{2.5}$, and PM_{10} were found to be 15.11ppm, 90.66 $\mu g/m^3$ and 82.44$\mu g/m^3$ respectively at Kofar Wambai and 33.77ppm, 40.22$\mu g/m^3$ and 44.88$\mu g/m^3$ at Kantin Kwari market respectively while the average values of CO, $PM_{2.5}$, and PM_{10} at Sabon Gari market was found to be 16ppm, 128$\mu g/m^3$ and 65$\mu g/m^3$ respectively as seen in figure 2. The average concentration values of CO and PM_{10} were found to be below the US EPA standard as seen in table 5. $PM_{2.5}$ was found to be the most abundant pollutant which is above the USEPA standard limits in all of the three locations, that is SA_1, SA_2 and SA_3.

Table 6: Correlation between $PM_{2.5}$ and Temp, W/Speed, W/Direction and R/Humidity.

S/N	Location	$PM_{2.5}$ ($\mu g/m^3$)	TEMP. (^0C)	W/Speed (m/s)	W/Direction (Degrees)	R/Humidity (%)
1	Kofar Wambai	90.66	32.4	10	100	25
2	Kantin Kwari	40.22	31.6	10.3	80	24
3	Sabon Gari	128	32.8	9.4	100	21
Correlation coefficient			0.99	-0.92	-0.75	-0.27

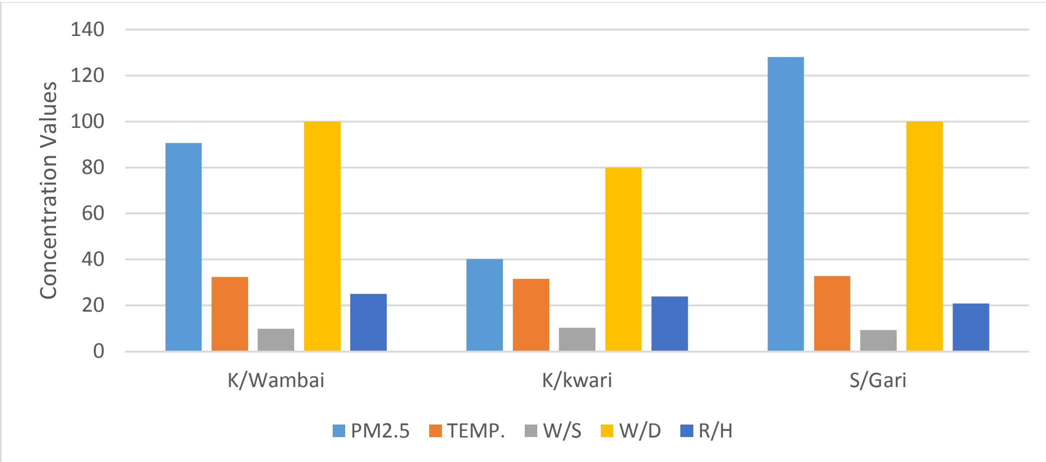

Figure 3: Relationship between PM2.5($\mu g/m^3$), **TEMP** (^0C), **W/S** (m/s), **W/D** (Degrees) **and R/H** (%)

From Table 6, there is a significant positive relationship between $PM_{2.5}$ and average temperature which indicate the increase in the concentration with temperature. However, there is a significant negative correlation coefficient between $PM_{2.5}$ and the average wind speed and direction, which shows the decrease in the concentration of $PM_{2.5}$ with the increase in wind speed and direction respectively. Moreover, there is also a negative correlation between $PM_{2.5}$ and Relative Humidity which shows that as relative humidity increases, the concentration of $PM_{2.5}$ decreases as shown in figure 3 above.

CONCLUSION

The study reveals that combustion-related pollution from vehicles and other sources in Kano city is significant with possibly severe health consequences. A statistically significant positive association was observed between $PM_{2.5}$ with temperature. There is a negative and statistically correlation between $PM_{2.5}$ with wind speed, wind direction and relative humidity, which exhibited a washing effect evidenced by its negative correlation with fine particle fractions. Wind speed spreads the pollutants thereby reducing their concentration. The results of the highest level obtained for the air pollution indicator for CO were; 40ppm, at SP_5 for day 1, 47ppm and 41ppm at SP_5 for days 2 and 3 respectively. The concentration of $PM_{2.5}$ was highest at SP_2 with a value of 184 $\mu g/m^3$ on day 3 and the highest concentration of PM_{10} was observed to be 169 $\mu g/m^3$ at SP_2 on day 1. However, the three monitored air pollutants when compared with AQI levels (Air quality index) were in the range of poor to moderate and moderate to poor for CO at SP_5, poor to very poor for $PM_{2.5}$ at SA_1, SA_2, SA_3 and very poor to poor for PM_{10} at SP_2. It was generally observed from the result that $PM_{2.5}$ was found to be the most abundant air pollutant in all three areas. The study, clearly points out that wind and temperature are the most important meteorological parameters influencing the behaviour of air pollutants which includes spread and transportation. However, analysis of the temperature, wind and relative humidity alone will not adequately explain the variability in the concentrations of air pollutants. Also, the number of sources of emission and aerosolization from surfaces (emissions of aerosol particles by vehicles travelling on the city's narrow roads, industry and resuspended soil dust) affect the concentration of air pollutants. Based on this it can be shown that fine particulate mass dominance is due to automobile source emissions in the area. The results showed that temperature, humidity and wind are the most important factors influencing the pollutant concentrations in Kano city.

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