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Geostatistics of pollutant gases along high traffic points in Urban Zaria, Nigeria

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ABSTRACT

This study was aimed at utilizing Geo-information technology in assessing the ambient air quality along some busy roads in urban Zaria. Samples were collected from ten (10) different sites. Parameters measured include: PM10, CO, NO2 and NH3 were measured in this study. Also included were: temperature, humidity and traffic volume/composition. The results displayed in a hazard map indicates that the concentrations of pollutants measured at all sampling points, with exception of the control site were within and above the hazard limits set by FEPA. This reveals that transport-related pollution in urban Zaria can be potentially hazardous to health. The main finding of this research is the comparison between spatial and non-spatial analysis approaches, which indicates that correlation analysis and buffer analysis of GIS using the concentration levels of detected air pollutants is relative method for assessing the health effects of air pollution.

Key Words: Air pollution, exposure assessment, environment, transport, GIS.

1. Introduction

Man and his environment are part of nature that is subjected to natural changes in order to maintain the dynamic equilibrium of the ecosystem. However in the present day, man's desire for rapid development in materialistic sense has compelled him to exploit the natural environment carelessly. This has resulted in the alteration of man's natural environment with consequential problems which are now being felt (Sharma and Singh, 1992), Transport or transportation is the movement of people, animals and goods from one location to another. Man's desire for rapid development in transportation includes air, rail, road, water, cable, pipeline, and space. The field can be divided into infrastructure, vehicles, and operations. Transport is important since it enables trade between peoples, which in turn establishes civilizations (Transportation, 2013),

Ambient air quality refers to the quality of outdoor air in our surrounding environment. It is typically measured near ground level, away from direct sources of pollution (Ambient, 2013), Surface transportation is a large source of greenhouse gas (GHG) emissions, and therefore large contributor to global climate change (Barth and Boriboonsomsin, 2008), Motor vehicles produce more air pollution than any other single human activity (World Resources Institute, 1997), In most developing countries of the world vehicular growth has not been checked properly by environmental regulating authorities leading to increased levels of pollution (Han, and Naeher, 2006), Traffic emissions contribute about 50-80% of NO_2 and CO concentration in developing countries (Fu, 2001; Goyal, 2006), This situation is alarming and is predicated on the poor economic disposition of developing countries. Poor vehicle maintenance culture and importation of old vehicles, which culminates in an automobile fleet dominated by a class of vehicles known as ''super emitters'' with high emission of harmful pollutants, has raised high this figure of emission concentration (Ibrahim, 2009), The increase in this traffic-related pollution is not based on the aforementioned factor only, but also on low quality fuel, poor traffic regulation and lack of air quality implementation force. These are clear indices to high levels of traffic-related pollution in developing countries. In Nigeria as well as in other developing countries, which are not yet fully industrialized, majority of the air pollution problems result from automobile exhaust (Ayodele and Bayero, 2009), In the major towns of some developing countries, because of tropical nature of the climatic conditions, many activities are performed outdoors. People stay along the busy roads every day either to do their work or to sell their wares. Therefore, the ill-effects on health due to air pollution resulting from automobile exhaust emission must be very serious indeed (Ayodele and Bayero, 2009), Also much attention is given to general industrial pollution and pollution in oil industries, with little reference to damages caused by mobile transportation sources of air pollution (Faboya, 1997; Magbagbeola, 2001; Iyoha, 2002),

Koku and Osuntogun (2007) studied three cities of Nigeria: Lagos, Ibadan and Ado – Ekiti all in South-west region of Nigeria has significant air quality pollution. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The obtained results of CO, SO_2, NO_2, and particulate counts per minute were to be higher than FEPA limits. Conclusions of this investigation show a growing risk of traffic-related problems in these Nigerian cities and therefore recommended for serious air quality measures.

Moen (2008) carried out a study in which ambient hourly concentrations for CO, NO_2, and SO_2 at six major intersections in Abuja were monitored during morning, low-traffic hours and during afternoon, high-traffic hours. These concentrations served as a model of exposure for traffic wardens, a high exposure group. The results showed that 'vehicle emissions are having a negative impact on air quality, and that traffic wardens have a high prevalence of symptoms that are possibly related to and are exacerbated by exposure to vehicle emission. Clearly, air quality management should be a greater priority in Abuja, and the effect of vehicle emissions on air quality and health should be studied further if public health is to be protected'.

Abam and Unachukwu (2009) reported the results of the investigation of vehicular emissions in selected areas in Calabar Nigeria. All the five monitored air pollutants when compared with AQI level (Air quality index) were in the range of: CO – poor to moderate and moderate to poor in different locations. SO_2 – was from very poor to poor, NO_2- from very poor to poor, PM_{10} was poor at all locations. The study concluded that transport-related pollution in Calabar is indeed significant with possible severe health consequences.

Okunola et al. (2012) conducted a research in Kano-Nigeria using the Crowcon gas sensor to collect emission values of various gases. They concluded that 'the concentrations of the CO, H_2S, NO_2 and SO_2 measured, with few exceptions, at some sites were above the AQI stipulated by USEPA especially during the dry seasons. This implies that traffic emission within Kano metropolis is not within the safe limits. Hence, the results reveal that transport-related pollution in Kano metropolis is significant with potentially hazardous health consequences'. It is well known that environmental pollution is a product of urbanization and technology, and other factors of population density and industrialization (Olade, 1987), Cities in developing countries are facing many problems related to rapid urbanization, aggravated by the present concern for climate change. This is because sustainable development requires the close monitoring of cities' environmental impact and therefore ecological footprint which include the determination of pollutant concentration level of vehicle emission by all kinds of transport is one of the tools employed. Affordable energy not only fuels our vehicles and electrical plants, it also fuels our economy and our quality of life. In cities like Lagos, Kano, Kaduna and Abuja, the rural-urban migration activated by the search for increased incomes has resulted in the concentration of large populations, traffic jams and legendary 'go-slow' of vehicular movement. These activities send pollutants into the atmosphere.

Isaac (2013) reported that automobiles in Nigeria are mostly fairly used (high mileage vehicles) and called on government to enact a law that will restrict the importation of cars beyond ten (10) years into the country, in a research conducted in 1994 under the Federal Ministry of Environment revealed that Nigeria's transportation sector as a whole accounted for 41 percent of CO_2, 83 percent of CO, 59 percent of NO_2, 98 percent of SO_2 and PM.

2. Research problem

Zaria urban area is rapidly increasing (Abbas and Arigbede, 2011), This relatively indicates that traffic movement is also increasing. Added to this, most of the vehicles imported into Nigeria are fairly used (Saidu, 2011); the conditions of the vehicles/motorcycles used majorly for commercial transport within Zaria urban area are in a very terrible state. Thereby rapidly increasing the quantity of pollutant gases emitted into the atmosphere. The gap identified and that shall be filled by the study examined the emission values for high traffic points in Zaria urban area. This will be achieved through determining the volume and composition of vehicular movements within the various sampling points, emission concentration levels of Particulate Matter (PM), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Ammonia (NH_3) within the various sampling points and their comparison with the Federal Environmental Protection Agency (FEPA) standard limits and finally creating a geospatial database and hazard map for Zaria urban area. This study intends to identify the potential health threat being faced by neglected children (Almajiri), street cleaners, street hawkers, commuters, and traffic wardens etc who are mostly located within these high traffic points.

2.1 Research questions

1. What is the volume and composition of vehicular movement along high traffic points in urban Zaria?
2. What are the types of vehicle gas emissions that are likely to be detected along high traffic points in Zaria urban area?
3. What are their emission levels and its comparison to the Federal Environmental Protection Agency (FEPA) limits along these high traffic points?
4. To what spatial extent is the township within these high traffic points, likely to be affected?

3.0 Materials and methods

3.1 The study area

Zaria urban area is located in the central plains of the northern Nigeria highlands standing at an average height of 670m above mean sea level. It is the second largest city in Kaduna State with a geographical position located between East longitudes 7° 36' 00" – 7° 46' 00" and North latitudes 11° 02' 00" – 11° 12' 00". It comprises of parts of Zaria and Sabon-Gari Local Government Areas covering about 70km from the west to east and roughly cover 8,950 square kilometers.

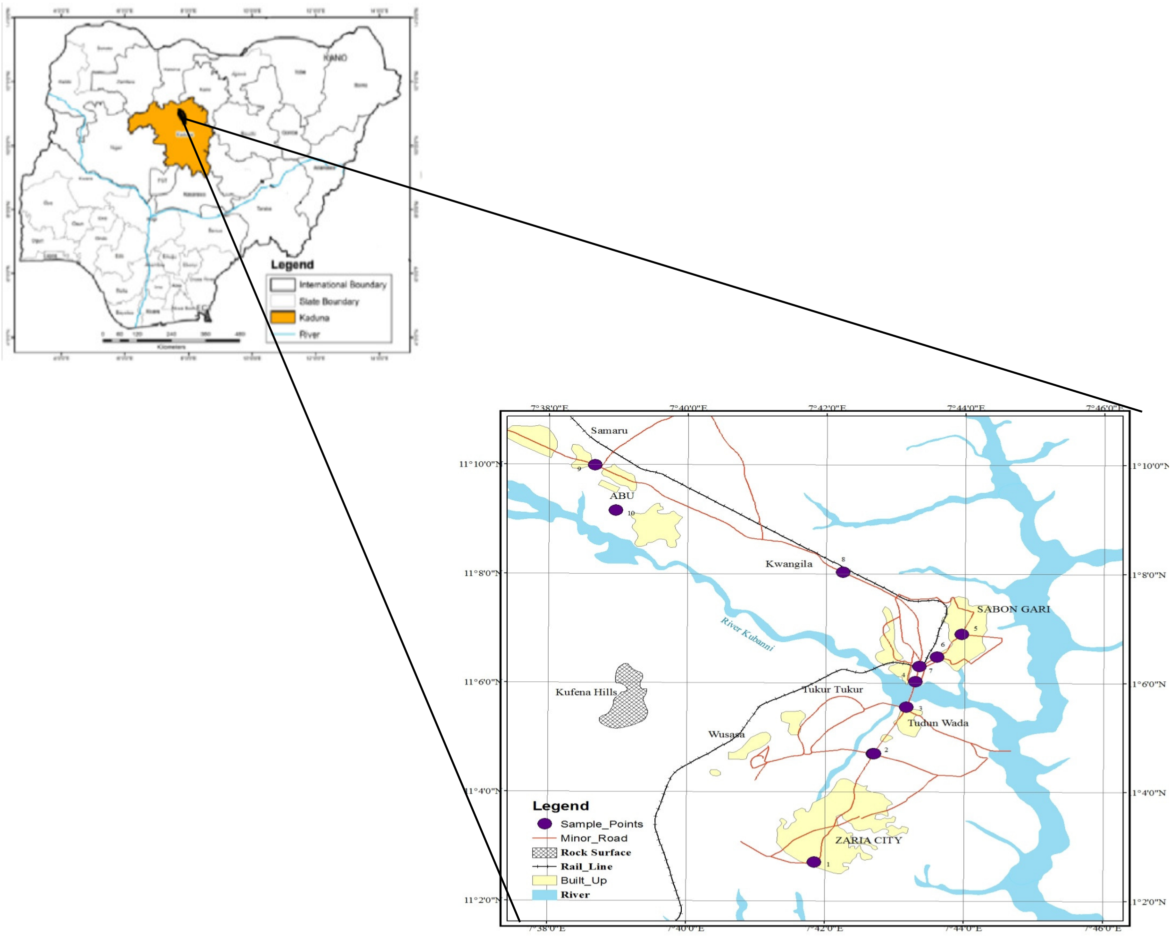


Figure 1: Distribution of sampling points (Topographic Map of Zaria Sheet 102)

It is drained by three major rivers namely: River Kubanni, River Saye and River Galma. The climatic characteristic is that of tropical savanna (Mortimore, 1970), According to the National Population Commission, the population of Zaria and Sabon Gari Local Government Area were totaled to be 695,069 people (NPC, 2006), The scope of this research was limited to major traffic points within urban Zaria. These are road intersecting points with high concentration of vehicles/motorcycles, concentration of businesses/commuters and also at these points; most vehicles are static with their engines still running. The spatial extent of the research covers Zaria City market, Kofar Doka roundabout, PZ junction, Kwangila under the bridge, Sabon Gari Market, Samaru Market, and Tudun Wada Agwaro Junction (See Figure 1),

3.2 Sampling

This study was conducted in October 2012.. Concentrations of gaseous pollutants data, Carbon Monoxide (CO), Nitrogen Dioxide (NO_2) and Ammonia (NH_3) were determined using mobile gas sensors (Gasman) manufactured by Crown Detection Instrument Ltd. Particulate Matter (PM) was measured using Particulate Matter (PM_{10}) Dust meter. Relative humidity and temperature were determined using TOP portable humidity and temperature meter. A motorcycle was used as the mode of transportation for easy maneuver through traffic congestion. Volume and composition of vehicular movements within the various sampling points can be seen in Table 1

Table 1: Geographical Coordinates of Sample Points with their average traffic count

	Latitude	Longitude	Motor/Cars	Motorcycles	Trucks
Zaria City Market	11° 27' 00"	7° 41' 49"	23	51	0
Kofar Doka R/A	11° 04' 30"	7° 42' 40"	52	95	4
Tudun Wada Agwaro R/A	11° 05' 35"	7° 43' 12"	64	117	2
Park Road R/A	11° 06' 04"	7° 43' 19"	58	101	2
Kalabari Off Aminu Rd Junction	11° 06' 58"	7° 43' 59"	27	151	1
Total Filling Station Junction	11° 06' 32"	7° 43' 37"	44	87	2
PZ Samaru Bustop	11° 06' 22"	7° 43' 23"	49	88	1
Kwangila Bridge	11° 08' 06"	7° 42' 14"	84	104	10
Samaru Market	11° 10' 01"	7° 38' 38"	35	47	3
ABU Staff School	11° 09' 11"	7° 38' 56"	2	3	0

3.3 Statistical analysis

Histograms/charts (Figures 2 – 5) were designed to show the variation between the recorded emission levels and the Federal Environmental Protection Agency (FEPA) safe limits (FEPA, 1991), Pearson's correlation analysis (Table 2) was used to determine if there is significant relationship between pollutant gases detected, meteorological and traffic data. Statistics were done using Microsoft Excel 2007 and the comprehensive statistical software (SPSS Version 20),

3.4 Geospatial analysis

A geospatial database (Figure 6 – 8) was created in the ArcGIS 9.3 software environment. It contained the following data fields: Name of location, Coordinates, Traffic count, Type of land use, Emission values for the various gases detected and ranking status (No Hazard, Low Hazard and High Hazard), Buffering analysis (Figure 9) was carried out to determine the extent of the township most likely to be at risk since even though as these pollutant gases have no political boundary, it is believed that those directly exposed or more closer to these sources of emission will be more at risk than those far away from the same sources of emission. As there is no consensus on the distance at which these health effects diminishes to background levels, Jerrett et al. (2010) in their Health Effects Institute (HEI) report recommended buffer analysis for 50m and 100m from the traffic sampling points, from which the percentage of built up area within these sampling points and population likely to be affected, will be determined. A hazard map, which was based on the combination of concentrations of the various gases detected, was produced (Figure 10),

4. Results and discussion

The results obtained for the analysis of pollutant gases concentration are shown in the Figures below.

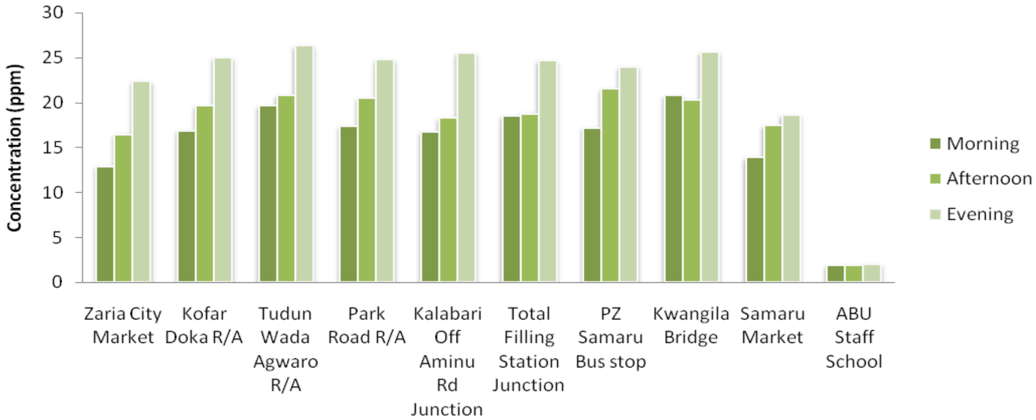


Figure 2: Mean Variation of Carbon monoxide (CO) across periods at sampling points

From Figure 2, the mean concentration of CO recorded was high at all sites, with the highest at Tudun Wada sampling point. This could be attributed to other sources of pollution at these sampling sites apart from that of traffic. This could be from stationary source i.e. burning of dump refuse and expired vehicles tyres at Tudun Wada and PZ-Samaru bus stop sampling points. The atmospheric CO along the corridors of these sampling points when compared with values reported in literature was found to be higher than average range of 1.6 - 3.8 ppm atmospheric concentration of urban air pollutants in Athens, Greece as reported by Kalabokas et al., (1999), It is also higher than the range of 0.7 - 1.9 ppm in Jahara, Kuwait found out by Ettouney et al., (2010), However, the values in this study were lower than range of 233 - 317ppm reported in three cities of Nigeria: Lagos, Ibadan and Ado - Ekiti (Koku and Osuntogun, 1999), Comparing the values of CO at the 10 sampling points, the highest value was recorded at Tudun Wada due to traffic congestion, commercial congestion and refuse burning. This site is located in between a congestion of local market, vehicle spare parts market, a motor park, gas filling station and refuse dump few meters away. It also serves as bus-stop for most intra-city buses, taxies and motorcycles thereby experiencing flux of traffic, especially during the afternoon-evening hours.

In the analysis of NO_2 in Figure 3, the concentration recorded was high at all sites, with the highest at the same Tudun Wada sampling point. Also, when the levels of NO_2 were compared with values reported in literature, periodic mean of NO_2 was found lower than 35 – 108 ppm reported in Athens, Greece by Kalabokas et al., (1999), lower than 0.20 - 0.521ppm reported for Calabar metropolis, Nigeria (Okafor et al., 2009), lower than 0.14 - 1.09 ppm reported for Kano metropolis, Nigeria (Okunola et al., 2012) but quite high when compared with the limits set by FEPA (1991) for NO_2 which is 0.06 ppm. This is most likely due to high traffic density and stationary fuel combustion process emissions from running of generators (Etiuma et al., 2006) which is very common within the Zaria urban area due to erratic power supply.

The concentration of Particulate Matter (PM_{10}) as indicated in Figure 4 below. The data analyzed result of PM_{10} revealed that the AQI rating is moderate unlike the earlier pollutant gases which were very poor. High values at PZ and Kwangila sampling points can be attributed to high traffic resulting in grid locks and also location of refuse dumps close to these sites.

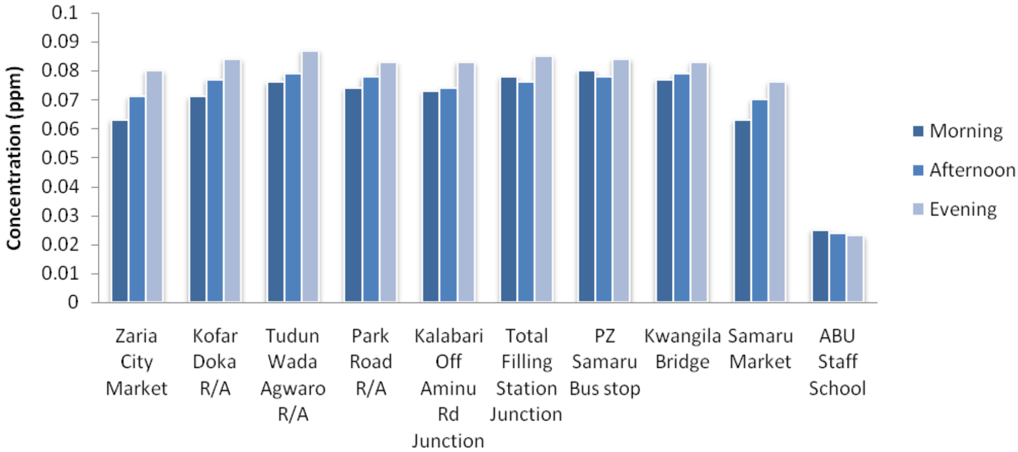


Figure 3: Mean variation of Nitrogen Dioxide (NO_2) across periods at sampling points

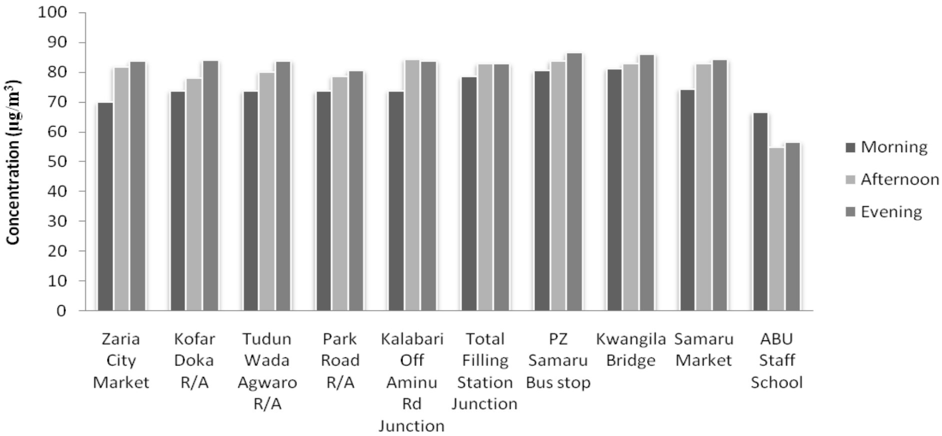


Figure 4: Mean variation of Particulate Matter (PM_{10}) across periods at sampling points

From the results obtained for Ammonia (NH_3) in Figure 5, we can see that the ambient area quality is acceptable for all the sites. This is because Occupational Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygienists (ACGIH) recommend 50 ppm and 25 ppm respectively for 8-hour exposure (Martin, 2008) and from the study Ammonia concentration level is lower than the stipulated standard.

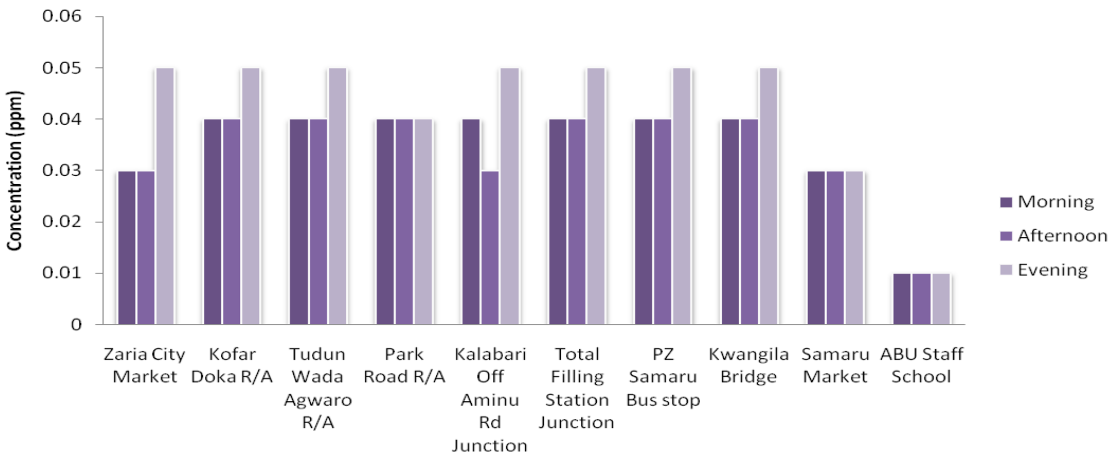


Figure 5: Mean Variation of Ammonia (NH_3) across periods at sampling points

Table 2: Correlation among air quality parameters, meteorological and traffic data

Parameter	PM	CO	NO_2	NH_3	Temp.	Traffic
PM	1					
CO	0.935**	1				
NO_2	0.958**	0.993**	1			
NH_3	0.898**	0.986**	0.973**	1		
Temperature	0.052	-0.110	-0.113	-0.145	1	
Traffic	0.751*	0.890**	0.838**	0.886**	0.060	1

**. Correlation is significant at the 0.01 level (2-tailed),
*. Correlation is significant at the 0.05 level (2-tailed),

From the result of geospatial database for the various emissions, query analysis were carried out using the ArcGIS 9.3 software as seen in Figures 6, 7 and 8.

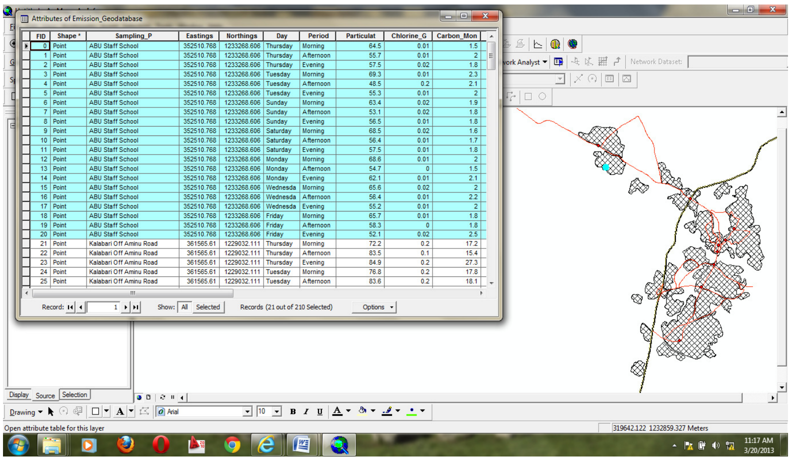


Figure 6: Geospatial Query showing ABU Staff School as the only sampling point where CO concentration is below 6 ppm

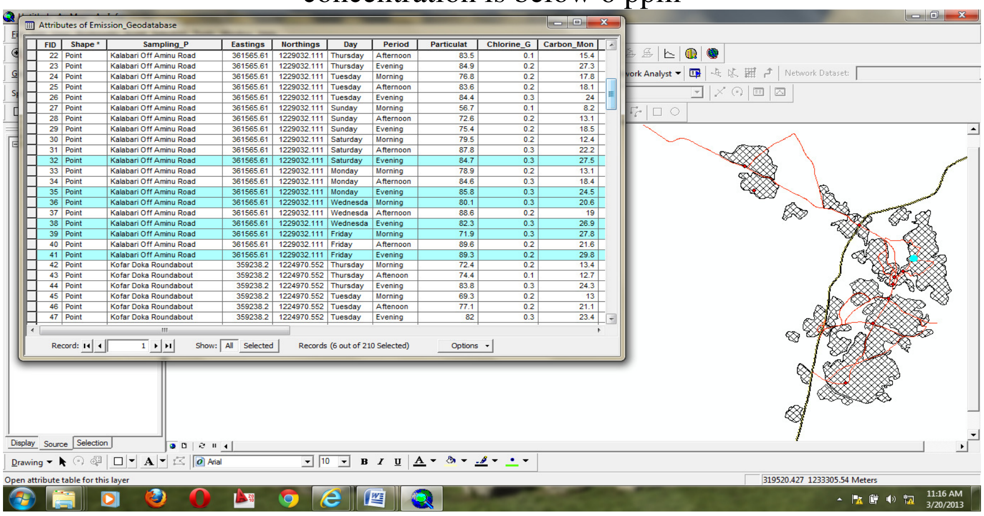
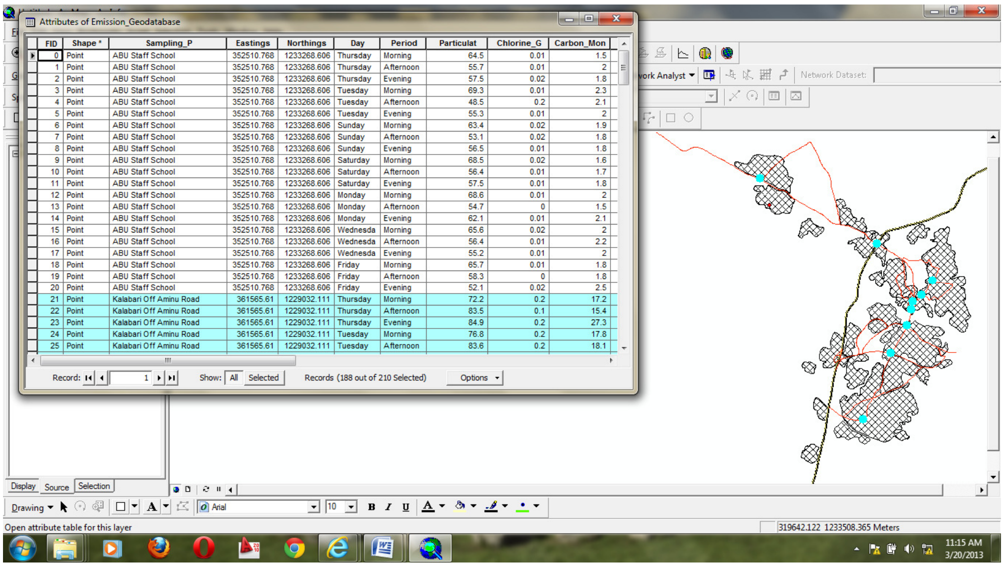


Figure 7: Geospatial Query showing Kalabari off Aminu road Sabon Gari as the only sampling point with motorcycle count above 200

Geospatial results can be seen in Figures 9 and 10. From the results obtained, findings showed that businesses/population within 100 - 500m away from these sample points are more prone and will be easily affected or will be faced with varying order of health effects resulting from exposure to these pollutant gases as well as noise. This is because the farther away one is from the sample points the less likely they will be exposure to these pollutant gases. Figure 10 is a hazard map with clearly indicates that all the sample points used for this research are hazardous because they are above the FEPA rating except that for ABU staff school sampling point which is below the FEPA limits for gaseous pollutants concentration levels. This could be attributed to many factors proximate are direction of wind, effect oif distance and availability and density of vegetation.



FID	Shape *	Sampling_P	Eastings	Northings	Day	Period	Particulat	Chlorine_G	Carbon_Mon
0	Point	ABU Staff School	352510.768	1233268.606	Thursday	Morning	64.5	0.01	1.5
1	Point	ABU Staff School	352510.768	1233268.606	Thursday	Afternoon	55.7	0.01	2
2	Point	ABU Staff School	352510.768	1233268.606	Thursday	Evening	57.5	0.02	1.8
3	Point	ABU Staff School	352510.768	1233268.606	Tuesday	Morning	69.3	0.01	2.3
4	Point	ABU Staff School	352510.768	1233268.606	Tuesday	Afternoon	48.5	0.2	2.1
5	Point	ABU Staff School	352510.768	1233268.606	Tuesday	Evening	55.3	0.01	2
6	Point	ABU Staff School	352510.768	1233268.606	Sunday	Morning	63.4	0.02	1.9
7	Point	ABU Staff School	352510.768	1233268.606	Sunday	Afternoon	53.1	0.02	1.8
8	Point	ABU Staff School	352510.768	1233268.606	Sunday	Evening	56.5	0.01	1.8
9	Point	ABU Staff School	352510.768	1233268.606	Saturday	Morning	68.5	0.02	1.6
10	Point	ABU Staff School	352510.768	1233268.606	Saturday	Afternoon	56.4	0.01	1.7
11	Point	ABU Staff School	352510.768	1233268.606	Saturday	Evening	57.5	0.01	1.8
12	Point	ABU Staff School	352510.768	1233268.606	Monday	Morning	68.6	0.01	2
13	Point	ABU Staff School	352510.768	1233268.606	Monday	Afternoon	54.7	0	1.5
14	Point	ABU Staff School	352510.768	1233268.606	Monday	Evening	62.1	0.01	2.1
15	Point	ABU Staff School	352510.768	1233268.606	Wednesda	Morning	65.6	0.02	2
16	Point	ABU Staff School	352510.768	1233268.606	Wednesda	Afternoon	56.4	0.01	2.2
17	Point	ABU Staff School	352510.768	1233268.606	Wednesda	Evening	55.2	0.01	2
18	Point	ABU Staff School	352510.768	1233268.606	Friday	Morning	65.7	0.01	1.8
19	Point	ABU Staff School	352510.768	1233268.606	Friday	Afternoon	58.3	0	1.8
20	Point	ABU Staff School	352510.768	1233268.606	Friday	Evening	52.1	0.02	2.5
21	Point	Kalabari Off Aminu Road	361565.61	1229032.111	Thursday	Morning	72.2	0.2	17.2
22	Point	Kalabari Off Aminu Road	361565.61	1229032.111	Thursday	Afternoon	83.5	0.1	15.4
23	Point	Kalabari Off Aminu Road	361565.61	1229032.111	Thursday	Evening	84.9	0.2	27.3
24	Point	Kalabari Off Aminu Road	361565.61	1229032.111	Tuesday	Morning	76.8	0.2	17.8
25	Point	Kalabari Off Aminu Road	361565.61	1229032.111	Tuesday	Afternoon	83.6	0.2	18.1

Figure 8: Geospatial Query showing sampling points that are hazardous

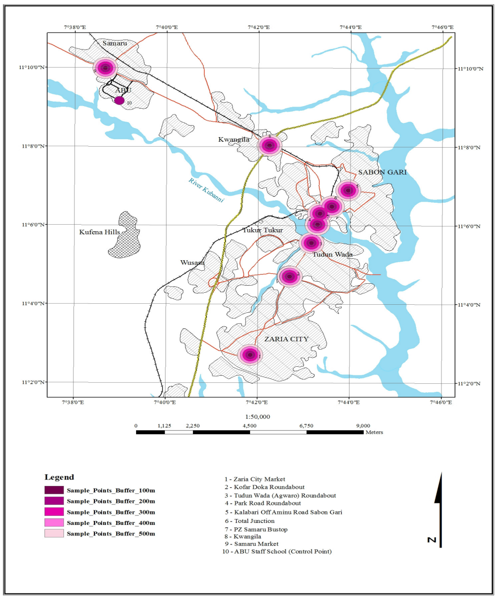


Figure 9: Hazard Buffer Zones around sampling points

5. Conclusion

The results of vehicular transportation pollution situation in the study area exhibit a dangerous picture of a growing urban area. It showed that traffic emissions in Zaria urban area include pollutants like CO, NO_2, and Particulate Dust (PM_{10}) as well as traces of NH_3. The concentrations of the CO measured, at most of the sampling points were above the FEPA standard limit. But as for NO_2 it was within the FEPA. Hence, the results indicate the possibility of transport-related pollution in urban Zaria being significant with potentially hazardous health consequences. The study also concludes that people residing or working in and around commercial locations in urban Zaria are likely to contract noise related ailments like temporary or permanent deafness, high blood pressure, headaches to mention a few. It is therefore recommended that to improve to the study will be to consider more elaborate time frame and traffic flow, to include meteorological factors such as wind factors and to study the relation of tailpipe emission to air pollution as well as health implications.

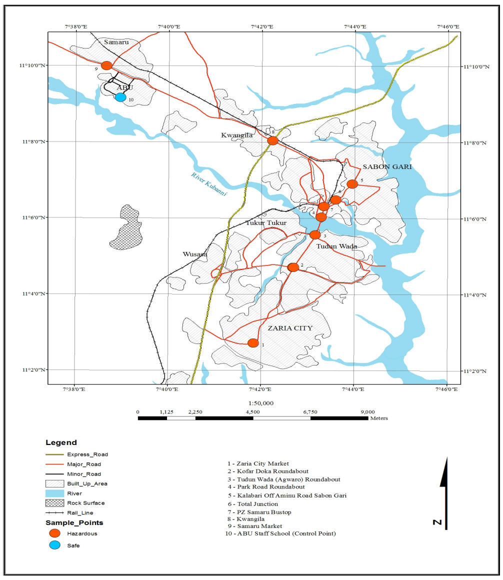


Figure 10: Hazard Map of Urban Zaria from vehicular emission

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