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Appraisal of Sulphur Contaminants from Transportation in Urban Zaria, Nigeria

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Abstract

As a step towards remediation of sulphur contaminants, this study used a Crowcon Gasman (gas detection instrument) to collect and analyze Sulphuric gas samples from densely populated areas of urban Zaria. The results showed varying concentrations of Sulphur Dioxide (SO_2) and Hydrogen Sulphide (H_2S). The high concentrations of these pollutants detected can be attributed to increased population growth, increased production of gaseous wastes and increased number of vehicular movement. The results indicate also that the concentrations of pollutant sulphur component SO_2 measured at all sampling points, with exception of the control site were hazardous while that of H_2S were within safe limit set by FEPA and ACGIH respectively. Statistical tests were performed which established significant variation/relationship between detected pollutants and traffic volume. Findings from this study imply that vehicular emission within urban Zaria is not within the safe limit which further reveals that transport-related pollution in Zaria urban area can be potentially hazardous to health.

Keywords: *Sulphur, Ambient Air, Health Hazard, Vehicle Emission and Pollution, Environment*

1. Introduction

Clean air is one of the basic requirements of human existence. However, air pollution continues to pose significant threats to human and environmental health worldwide. According to the World Health Organization (WHO), more than two million premature deaths each year can be attributed to the effects of urban outdoor and indoor air pollution and these effects are more prominent in developing countries (WHO, 2005a). Outdoor air pollution sometimes called ambient air pollution occurs in both rural and urban areas. However, the intensity and type of pollution depends on the available pollution sources.

Sulphur oxides and hydrogen sulphide are two major sulphur-containing air pollutants. Both cause great environmental concern. Most sulphur oxides are released in the form of sulphur dioxide, which reacts in the atmosphere to form sulphates. Findings have shown that these gases interfere with normal breathing patterns, reduce visibility, and contribute to the formation of acid rain (Wang *et al.,* 2005).

Sulphur is a naturally occurring part of crude oil and must be removed during the refining process. Despite this removal, some sulphur remains in finished products, including both gasoline and diesel fuel. When these fuels are burnt, Sulphur Dioxide (SO_2) and sulphate particulate matter are emitted. Reduction in the sulphur content of transport fuels will immediately reduce the emissions of these sulphur pollutants (ACFA, 2008).

Sulphur Dioxide is a colorless gas formed primarily during the combustion of a sulphur-containing fuel or sulphur-containing industrial waste gases. Once released to the atmosphere, sulphur dioxide reacts slowly because of photo-chemically initiated reactions and reactions with cloud and fog droplets, at rates of between approximately 0.1 percent and 3 percent per hour. These atmospheric reactions yield sulphuric acid, inorganic sulphate compounds, and organic sulphate compounds (Richards, 2000).

Hydrogen Sulphide (H_2S) is emitted from a number of metallurgical, petroleum, and petrochemical processes. Fugitive emission of Hydrogen Sulphide can occur from sour gas wells and certain petrochemical processes. It is a highly toxic gas due to its chemical asphixant characteristics. Despite its strong rotten egg odour, it is often difficult to detect at high concentrations due to rapid olfactory fatigue. Hydrogen Sulphide is highly soluble in water and can be easily oxidized to form sulphur dioxide (Richards, 2000).

The monitoring of air pollutants such as SO_2 and H_2S in ambient air has received substantial attention over the past several years because they are among the major pollutants which significantly affect the chemistry of the atmosphere and human health (Wu *et al.,* 2003). A recent study by WHO concluded that, "One of the trends predicted to lead to increasing air pollution levels is the high rate of urbanization in countries where most of the population is on low income. It is expected that the rapid growth in urban populations will lead to a dramatic increase in vehicle numbers combined with inexpensive solutions for daily commuting, more frequent use of older and two-wheeled vehicles, poor car maintenance and other developments that increase air pollution" (WHO, 2005b).

Sulphur emissions influence the level of acidification of soils and freshwater ecosystems (Stoddard *et al.,* 1999; Schopp *et al.*, 2003), climate change (Haywood and Boucher, 2000; Ramanathan *et al.*, 2001) and have impacts on human health (WHO, 2003; 2005b; 2006). The acidification situation was serious in large parts of northern Europe in the 1970s, mainly in the Fenno-Scandia region also due to slow weathering of soil and bedrock. Significant exceedances of critical loads were observed over large parts of central Europe, southern parts of Scandinavia and North-Western Europe (Lovblad *et al.,* 2004). Emission and successive deposition of sulphur have caused material, soil and forest damage (Nellemann and Goul Thomsen, 2001; Akselsson *et al.,* 2004) and surface water acidification.

WHO (2000) also reported that in dry unpolluted atmospheric conditions, it is estimated that the average SO_2 concentration for urban areas showed annual mean ranging from 20 to 60 μg/m^3 (0.0072 to 0.022 ppm) and daily means rarely exceeding 125μg/m^3 (0.045 ppm).

Riordan and Adeeb (2004) carried a study on SO_2 concentration level in four sample points (Christies Beach, Elizabeth, Northfield and Kensington) all within Adelaide metropolis. Their findings show that SO_2 concentration level did not exceed the 0.08ppm one-day standard stipulated by the National Environment Protection Measure (NEPM). Therefore, the concentration level is not likely to have an adverse impact on either human health or vegetation in the metropolitan Adelaide region.

Barman *et al.,* (2008) conducted a study on the ambient air quality of the city Lucknow, India during Diwali festival. Results showed varied concentrations of PM_{10}, SO_2 and NO_x for observations taken at four representative locations, during day and night times for Pre Diwali (day before Diwali) and Diwali day. On Diwali day, 24-hour average concentration of SO_2 was found to be 139.1μg /m^3 (0.05 ppm) and this concentration was found to be higher at 1.95 and 6.59 times higher when compared with the respective concentration of Pre Diwali and normal day. On Diwali night (12-hour) mean level of SO_2 was 205.4μg/m^3 (0.074ppm) which was 2.82 times higher than the daytime concentration.

This study intends to appraise the level of sulphur contaminants from transportation in urban Zaria as a result of tremendous increase in urbanization and vehicular ownership.

2. 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 transversing about 70km from the west to east and roughly cover 8,950 square kilometers. 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).

Figure 1: Map of Nigeria showing Kaduna State and Urban Zaria

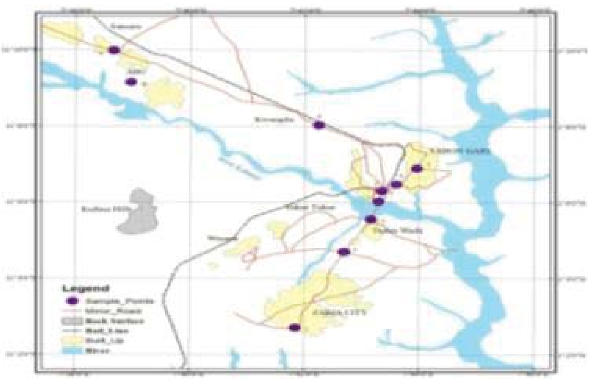

Figure 2: Distribution of sampling points (Topographical Map of Zaria, Sheet 102)

3. Materials and Methods

This study is an exposure assessment performed in Zaria urban area in the northern part of Kaduna state, Nigeria. After reviewing the map of the study area, ten (10) sampling points were selected (See Figure 2). These include: the Zaria city market, Kofar Doka roundabout (R/A), Tudun Wada Agwaro roundabout (R/A), Park road roundabout (R/A), Kalabari off Aminu road junction and Total filling station junction both in Sabon Gari, PZ Samaru Bus stop, Kwangila Bridge, Samaru market and Ahmadu Bello University Staff School which serves as a control point. A total of 210 samples were obtained from the selected areas during morning, afternoon and evening observation periods with 21 samples collected from each sampling point.

Traffic count was conducted to obtain statistics of car/motorcycle/truck movement in the various sampling traffic points. Concentration level of SO_2 and H_2S were measured using the Crowcon Gasman sensor. The Crowcon (Gasman) gas sensor which was rented from the Kaduna State Enviromental Protection Agency (KEPA) is a unique single-gas monitor for detection of flammable gases, oxygen and toxic gases. It offers flexibility, assurance, and robustness. Intrinsically safe, it is a portable gas detector with embedded software designed to the exacting requirements of International Electrotechnical Commission (IEC 61508-3) which is the international standard for electrical, electronic and programmable electronic safety related systems, guaranteeing reliable and dependable operation. It was used in this study to record emission values of hazardous gases detectable at these traffic points.

Concentration level of these pollutant gases was obtained for a 7-day period at various sampling points along major motor roads within commercial areas in urban Zaria at different times so that the survey is statistically representative of the existing conditions of the concentration level. These times were: 7:30 – 9:15am, 12:30 – 2:15pm and 4:30 – 6:15pm. Measurements were performed when wind was near static and temperature was averagely about 29.8, 40.3 and 30.9°C for morning, afternoon and evening sampling periods respectively. The raw data obtained from this study were analyzed using statistical methods. The sampling points over which measurements were done are as shown in Fig. 1 above and obtained SO_2 concentration level was compared with the Federal Environmental Protection Agency (FEPA) standard limit of 0.01- 0.1ppm (FEPA, 1991),

4. Results and Discussion

Results obtained for the volume and composition of vehicular movements within the various sampling points indicated in Figure 2, Figure 3. It showed that the volume of motorcycles is more than that of motors and trucks. Kwangila bridge sample point is a major junction which links Zaria City-Sabon Gari-Samaru and to other states like Katsina, Kano, Sokoto, Zamfara and Kebbi. While Kalabari off Aminu road junction sample point in Sabon Gari (which is the centre of commercial activity) has the highest number of motorcycles. This can be attributed to the fact that the Sabon Gari market is very close to the sampling point.

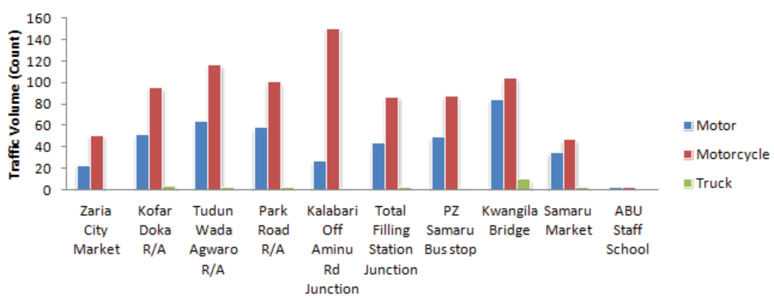

Figure 3: Average traffic volume across various sampling points

The concentration of Sulphur Dioxide (SO_2) ranged from 0.059 – 0.081 ppm for Zaria City market sample point; 0.069 – 0.084 ppm for Kofar Doka Roundabout; 0.078 – 0.086 ppm for Tudun Wada Agwaro Roundabout; 0.069 – 0.081 ppm for Park Road Roundabout; 0.068 – 0.081 ppm for Kalabari off Aminu Road Junction; 0.073 – 0.087 ppm for Total filling station Junction; 0.069 – 0.088 ppm for PZ Samaru Bus stop; 0.073 – 0.083 ppm for Kwangila under bridge; 0.057 – 0.075 ppm for Samaru market and 0.021 – 0.027 ppm for ABU Staff School which serves as the control point.

Table 1 and Figure 4 show the variation across sampling days and sampling periods respectively.

Table 1: Average Sulphur Dioxide (SO_2) Emission across sampling sites

	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Zaria City Market	0.081	0.071	0.073	0.072	0.074	0.059	0.069
Kofar Doka R/A	0.077	0.079	0.084	0.077	0.08	0.069	0.076
Tudun Wada Agwaro R/A	0.081	0.08	0.086	0.078	0.085	0.08	0.082
Park Road R/A	0.078	0.081	0.079	0.073	0.083	0.079	0.069
Kalabari Off Aminu Rd Junction	0.081	0.077	0.081	0.073	0.078	0.081	0.068
Total Filling Station Junction	0.084	0.078	0.085	0.073	0.087	0.079	0.074
PZ Samaru Bus stop	0.078	0.081	0.088	0.079	0.083	0.081	0.069
Kwangila Bridge	0.08	0.083	0.081	0.078	0.077	0.079	0.073
Samaru Market	0.075	0.073	0.072	0.062	0.073	0.065	0.057
ABU Staff School	0.022	0.026	0.02	0.027	0.023	0.021	0.027

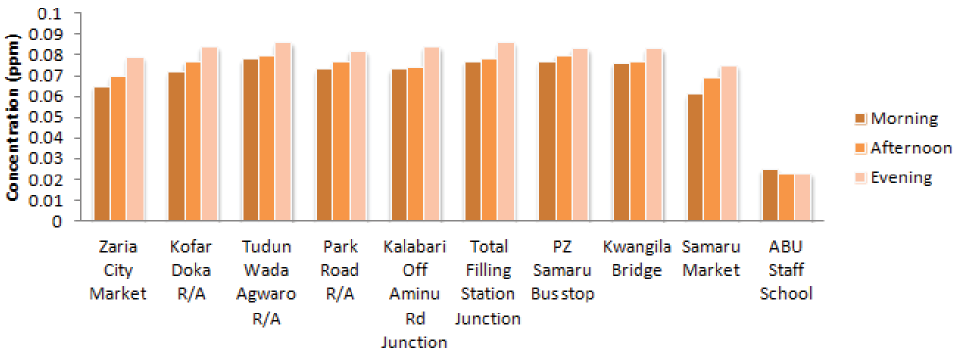

Figure 4: Mean Variation of Sulphur Dioxide (SO_2) across periods at sampling points

For Hydrogen Sulphide (H_2S), as stated in Table 2, the concentration level ranged from 0.42 – 0.66 ppm for Zaria City market; 0.50 – 0.69 ppm for Kofar Doka Roundabout; 0.60 – 0.73 ppm for Tudun Wada Agwaro Roundabout; 0.54 – 0.67 ppm for Park Road Roundabout; 0.55 – 0.69 ppm for Kalabari off Aminu Road Junction; 0.58 – 0.69 ppm for Total filling station Junction; 0.55 – 0.75 ppm for PZ Samaru Bus stop; 0.53 – 0.74 ppm for Kwangila under bridge; 0.43 – 0.64 ppm for Samaru market and 0.18 – 0.26 ppm for ABU Staff School which serves as the control point. Variation of H_2S along the various sampling points is further displayed in Figure 5

Table 2: Average Hydrogen Sulphide (H_2S) Emission across sampling sites

	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Zaria City Market	0.61	0.66	0.63	0.63	0.64	0.42	0.63
Kofar Doka R/A	0.56	0.7	0.65	0.64	0.71	0.5	0.69
Tudun Wada Agwaro R/A	0.62	0.73	0.7	0.61	0.72	0.6	0.69
Park Road R/A	0.62	0.71	0.67	0.55	0.69	0.54	0.6
Kalabari Off Aminu Rd Junction	0.66	0.66	0.68	0.69	0.64	0.55	0.58
Total Filling Station Junction	0.64	0.69	0.67	0.69	0.68	0.58	0.69
PZ Samaru Bus stop	0.64	0.73	0.75	0.76	0.71	0.55	0.56
Kwangila Bridge	0.6	0.74	0.68	0.73	0.67	0.53	0.63
Samaru Market	0.62	0.64	0.63	0.46	0.61	0.43	0.49
ABU Staff School	0.18	0.26	0.2	0.21	0.19	0.21	0.23

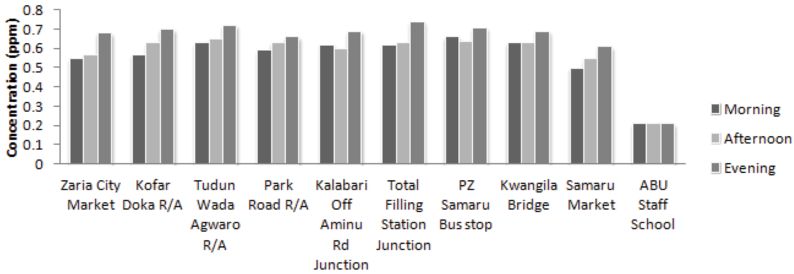

Fig. 5: Mean Variation of Hydrogen Sulphide (H_2S) across periods at sampling points

From Figures 4 and 5, there is clear indication that on the average, evening periods recorded the highest level of SO_2 concentration. This can be attributed to flexibilty of the morning traffic whereby commuters/vehicle owners move at varying time-frames from as early as 6.30am for the primary/secondary student and working class and as late as 9.30am for the business operators/marketers. While for the evening traffic hours, the same workers who leave home as early as 7am do not have the laxity of closing work earlier than 3.45pm. This coincides with secondary school students extra moral lesson closing rush and market closing rush all on a limited access route. These is in agreement to the findings of high evening and lower morning periods of pollutant gases concentration as reported by Ragini *et al*. (2009); Okunola *et al.* (2012) where concentration of pollutant gases was lowest in the morning period.

However taking one of the sampling points into consideration (Kwangila which records most of the high concentration levels) it can be seen in Figures 6 and 7 below that not all evening periods record higher concentration levels of SO_2 across the sampling days. While other days had higher evening concentration levels, Friday had a higher concentration during the afternoon period. This can be attributed to the fact that the sampling point (Kwangila) serves as a transit route for travellers going to other north-western states which run into the evening hours. Also Saturday morning period had the highest concentration for the day. This also can be attributed to the continuous travelling activities at the Kwangila bridge sampling point while the close gap for afternoon and evening periods can be attributed to the fact that most wedding events occur on that day.

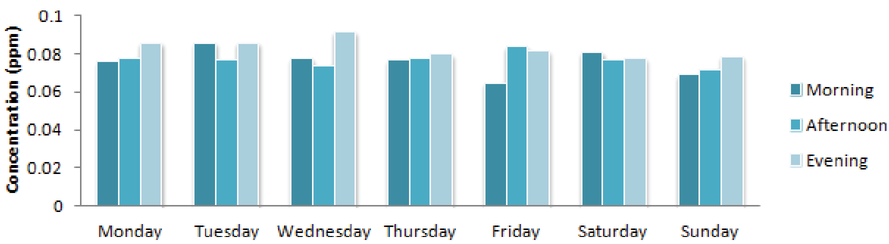

Fig. 6: Variation of Sulphur Dioxide (SO_2) across periods at sampling days for Kwangila

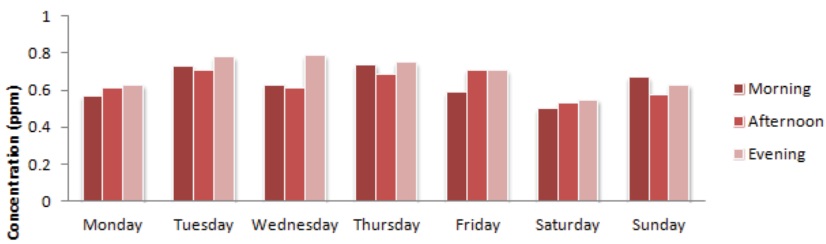

Fig. 7: Variation of Hydrogen Sulphide (H_2S) across periods at sampling days for Kwangila

From the results obtained for SO_2 and H_2S, it can be seen that highest level of SO_2 was recorded still at the Tudun Wada sampling point. Positive significant correlation at 0.01 and 0.05 levels (Table 5 below) between SO_2 and Motorcycles/cars during this season could be responsible. Furthermore, the concentration of SO_2 is lower than ranges of 3.21 – 5.18 ppm, 7.4 – 15.5 ppm, and 16 – 64 ppm reported by Ayodele and Abubakar (2010), Ettouney *et al*. (2010), and Kalabokas *et al*. (1999), respectively but was with the range of 0.03 – 0.09ppm reported in Kano metropolis, Nigeria (Okunola *et al.,* 2012). The reasons for these values at these points may be attributed to several processes such as, refuse dumpsite located along these sites. Comparing data with the FEPA standard level of 0.06 ppm, the air quality for SO_2 ranged between moderate and poor (between the stipulated 0.01 – 0.1) in most of the sampling sites while at the ABU Staff School which is the control site, AQI for SO_2 was good.

For H_2S, the ambient area quality is acceptable for all the sites. This is because even though (WHO, 1981) stated that "there is no international standards for H_2S, many countries have adopted 'short time' standards". Since FEPA has no quality standard for H_2S, this study is compelled to compare with an international standard. ACGIH, (2005) announced their intention to lower the time-weighted-average (TWA) work-day limit from 10 ppm to 1 ppm and for short-term (15 minutes) exposure limit from 15 ppm to 5 ppm. From this it can be said that, even with a dump site close to some of the sampling points, the concentration level of H_2S is still within safe limits.

Tables 3 and 4 present summary of statistical analyses (ANOVA and Pearson's correlation) that was conducted to determine if there was any variation/relationship between detected pollutant gases SO_2 and H_2S with traffic volume at p = 0.05 significant level.

Table 3: Analysis of Variance (ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
SO_2	Between Groups	.057	9	.006	90.553	.000
	Within Groups	.014	200	.000		
	Total	.070	209			
H_2S	Between Groups	3.639	9	.404	48.834	.000
	Within Groups	1.656	200	.008		
	Total	5.295	209			
Cars	Between Groups	101621.981	9	11291.331	36.334	.000
	Within Groups	62153.714	200	310.769		
	Total	163775.695	209			
Motorcycles	Between Groups	322928.671	9	35880.963	28.316	.000
	Within Groups	253431.810	200	1267.159		
	Total	576360.481	209			
Trucks	Between Groups	1515.448	9	168.383	13.970	.000
	Within Groups	2410.667	200	12.053		
	Total	3926.114	209			

Table 4: Correlation between detected SO_2 and H_2S with traffic volume

	SO_2	**H_2S**	**Cars**	**Motorcycles**	**Trucks**
SO_2	1	0.998**	0.718*	0.791**	0.344
H_2S	0.998**	1	0.700*	0.792**	0.319
Cars	0.718*	0.700*	1	0.585	0.758*
Motorcycles	0.791**	0.792**	0.585	1	0.297
Trucks	0.344	0.319	0.758*	0.297	1

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

Table 3 confirmed that there is significant variation between grouped as determined by one-way ANOVA (F (9, 200) = 90.553; 48.834; 36.334; 28.216; 13.970) for SO_2, H_2S, Cars, Motorcycles and Trucks respectively.

This result is also subjected to correlation (See Table 4) which indicates a strong significant correlation ($p < 0.01$) between detected sulphur contaminants (SO_2 and H_2S) with motorcycles while the correlation with cars is at $p < 0.05$ significant level. There was no correlation between the detected pollutant gases with heavy duty vehicles (trucks). This can be attributed to the fact that only three (Kofar-Doka Roundabout, Kwangila bridge and Samaru market) out of the ten sampling points recorded significant number of trucks. But there was correlation ($P < 0.05$) between cars and trucks. This can also be attributed to their orderly movement along access routes unlike motorcycles which move in clusters.

5. Conclusion

An analysis of Sulphur Dioxide and Hydrogen Sulphide from vehicular emission in ambient air of urban Zaria showed the presence of the various degrees of these pollutants. Varying concentrations of these gases were detected at all sampling points, with exception of the control site. It is imperative therefore that the expansion of urban Zaria road network, standard control measures and proper waste disposal methods should be quickly put in place to avoid continuous emission that may lead to increased concentration of these pollutants. It is recommended that extensive awareness campaigns be carried out and further study will be appropriate to ascertain and proffer mitigation measures on their effects on humans and the environment.

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