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SPATIAL AMBIENT AIR QUALITY ANALYSIS AND ITS EFFECTS ON THE TRAFFIC POLICE OFFICERS WITHIN THE CENTRAL BUSINESS DISTRICT IN NAIROBI, KENYA

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Abstract
Every person in Kenya is entitled to a clean and healthy environment. This includes the access to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes. As a practice, the traffic police officers (TPO's) spend most of their time on the road controlling traffic a routine that exposes them to automobile emissions. This study was therefore carried out to investigate the levels of exposure to automobile emissions and to determine the health effects of exposure. Emissions of carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_x) from vehicles in the Central Business District in Nairobi were sampled. A gas aspiration pump AP-20 together with detector tubes were used to determine the levels of NOx, CO emissions while Testo 435 multi-function measuring instrument was used to determine CO_2 levels, wind velocity and temperature at ten purposely selected sites within the Central Business District. The results showed that CO_2, CO and NO_x sampled had means of 634.80 parts per million (ppm), 12.74 ppm and 2.56 ppm respectively. These results demonstrated that the TPO's were exposed to CO, CO_2 and NO_x levels that were above the recommended occupational exposure limits-control limit for the gases according to Legal Notice No. 60 of 2007 (GOK, 2007).

Key words: Air pollution, air quality, exposure, risk, health

1.0 Introduction

In Kenya, every person is entitled to a clean and healthy environment which includes the access to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes. (GOK, 1999). The World Health Organization contents that clean air is a basic requirement for human health and well-being even though air pollution continues to pose a significant threat to health worldwide. According to their assessment of the burden of disease due to air pollution, more than two million premature deaths each year can be attributed to the effects of urban outdoor and indoor air pollution caused by the burning of fuels. More than half of these disease burdens in particular respiratory complications are borne by the populations of developing countries Kenya included (WHO, 2002). Currently urban air pollution is increasingly being considered as a major public health problem (Schwartz, 1994; Salvi *et al*., 1999; WHO, 2001; Brunekreef and Holgate, 2002).

The lung is a critical interface between the environment and the human body and an average person takes about 10 million breaths a year and toxic substances in air can easily reach the lung and other organs where they can produce harmful effects (WHO, 2004). Both indoor and outdoor air contains chemical and biological gases, droplets and particles some of which are harmful to health. When these harmful elements are present in the air at concentrations adverse to animal health and the environment, the situation is considered as air pollution. In Kenya, inventory studies have revealed significant levels of air pollutants with potential high toxicities to man (MENR/UNEP, 2005).

According to data available from Kenya National Bureau of Statistics (KNBS) a total of 52,817 vehicles were registered in 2006, 85,324 in 2007 while 121,831 in 2008 (KNBS, 2009). This data together with Session paper No 4 of 2004 (GOK, 2004), reveal that there has been a rapid growing number of second-hand cars registered in Kenya a majority of which (25% – 35%) end up being used in Nairobi alone.

Additionally, other reports also indicate that cancer among the urban population in Kenya between the periods 2000 to 2002 was on an upward trend (Korir *et al.*, 2008) and malaria was the leading cause of morbidity followed closely by diseases of respiratory infections in the year 2005, 2006 and 2007 respectively (MOH, 2008). Statistics in Kenya also indicate that about 50 Kenyans die daily from various forms of cancer and about 80,000 cases of cancer are diagnosed each year in the world (Olick, 2011). The reports, however, failed to give the causal factors for cancer and respiratory ailments. This clearly gives a gloomy situation in Kenya. The little information available on automobile air pollution in Nairobi suggests high pollution emissions (Gatebe, 1992; Karue *et al.,* 1992 and Gatebe *et al.,* 1996). The causes of high emissions rates include road congestion which increases emissions per kilometre travelled, poor fuel quality including high lead content, inadequate emissions controls, poor maintenance and high average age of the vehicle fleet (Faiz and de Larderer., 1993). Similarly Mulaku and Kamau (2001) demonstrated that a similar situation and condition prevailed within Nairobi. In most cases, air pollution increases in direct proportion with the increase of the number of vehicles (Odhiambo *et al.,* 2010) in the absence of clear policies in the management of emissions from these motor vehicles. Vehicle age and lack of regular maintenance, poor infrastructure and economic inability are factors that were found to agravate air pollution situations in urban centres especially the Central Business District (Maina *et al*., 2005).

In Kenya, legal Notice No. 60 of 2007 (GOK, 2007) provides the recommended long term exposure limits as follows, 50 ppm for CO, 5000 ppm for CO_2, 3 ppm for NO_2 while short term exposure limits are given as 300 ppm for CO, 15000 ppm for CO_2 and 5 ppm for NO_2 respectively . WHO (2000) also provides long term exposure limits for CO and NO_2 as 9 ppm and 0.072 ppm respectively while short term exposure limits for the same gases are given as 26 ppm for CO and 0.12 ppm for NO_2 .

Studies that have been carried out in other parts of the world also revealed that exposure to automobile air pollution may lead to a variety of health effects. For example, a 2004 study in Ontario Canada found increased risk of mortality from heart and lung disease in people living within 100 meters of a roadway. New York city studies demonstrated that diesel trucks create air toxics hot spots at crossings, urban areas, bus stops, and bus depots (Kinny *et al.,* 2000 and Lena *et al*., 2002).

The traffic department is a department within the Kenya Police Service that is charged with ensuring that drivers on the road comply with the traffic Act and related subsidiary legislations. A majority of the traffic police staff have to spend much of their time on the roads while on duty.

The aim of this study was therefore to analyse ambient air quality in the Central Business District in Nairobi in relation to the health of the TPO's. To achieve this, samples of automobile CO_2, CO and NOx emissions in selected sites within the Central Business District were analysed.

2.0 Materials and Methods

The study was conducted through cross-sectional survey employing both qualitative and quantitative methods of data collection methods. During the study, it was hypothesized that automobile emissions in the Central Business District (Nairobi) are within the recommended thresh-hold limit and have no significant effect on the health of TPO's. A sample of 117 TPO's was drawn from the traffic department based at Central and Nairobi Area Police Stations, the two stations that operates within the Central Business District in Nairobi. Air sampling was collected at ten (10) purposively selected site as shown in Fig. 1. More data was also collected by use of questionnaires, interviews, observations at the sites and carrying out document analysis. A gas aspiration pump AP-20 together with detector/dragger tubes were used to determine the levels of NO_x and CO while Testo 435 multifunction measuring instrument was used to determine CO_2 levels, wind velocity and temperature. Both qualitative and quantitative data was collected between December 2009 and September 2011. Air sampling was carried out in the week during periods of high traffic density i.e in the morning (7.00 – 9.00 am), at noon (12.00 -2.00 pm) and in the evening (5.00 – 7.00 pm) at ten purposively selected sites within the Central Business District (Figure 1 and Table 1). Several readings were taken both during the wet and dry seasons. Descriptive and inferential analysis was used to analyse the data at a level of 95% confidence.

Fig. 1: Map showing air sampling sites locations: sampling sites★

Table 1: Sampling site name, notation and coordinates

	Name of Air Sampling Site	Notation	Coordinates
1.	University Way Round About	UWR	1^0 16’55.3’’S 36^0 48’54.5’’ E
2.	Fire Station Round About	FSR	1^0 16’53.1’’S 36^0 49’23.1’’ E
3.	Harambee Sacco Round About	HSR	1^0 17’33.0’’S 36^0 49’13.1’’ E
4.	Nyayo House Round About	NHR	1^0 17’10.6’’S 36^0 49’01.9’’ E
5.	Globe Cinema Round About	GCR	1^0 16’45.4 ’’S 36^0 49’18.9’’ E
6.	Kencom Bus Stage	KBS	1^0 17’07.8’’S 36^0 49’29.7’’ E
7.	Bomb Blast Round About	BBR	1^0 17’21.8’’S 36^0 49’38.3’’ E
8.	Junction Of Muhindi Bingu and Kenyatta Avenue	JMK	1^0 17’06.0’’S 36^0 49’14.4’’ E

9.	Junction Of Tom Mboya And Ronald Ngala Street	JTR	1^0 17’05.4’’S 36^0 49’35.5’’ E
10.	Wakulima Market Round About	WMR	1^0 17’16.3’’S 36^0 49’4795’’ E

3.0 Results and Discussion

3.1 Air Sampling Results

The results of automobile emissions sampled at various sites are shown in Table 2 below. The results show that CO_2 had the highest concentration as compared with the other gases with a mean value of 634.80 ± 23.13 ppm. The highest value of CO_2 was found at JTR sample site with a mean value of 675.25 ± 21.20 ppm while the lowest value was found at sample site BBR with a mean value of 605.50 ± 28.49 ppm. This was followed by CO with a mean value of 12.74 ± 0.51 ppm. The sample site with the highest concentration of CO was KBS with a mean value of 13.63 ± 0.46 ppm while the lowest value of CO was found at sample site UWR with a mean value of 12.26 ± 0.32 ppm. Finally NO_x had very low mean values as compared with both CO and CO_2.

Table 2: Temperature, wind velocity and automotive emission levels for CO, CO_2 and NO_x within the Central Business District, Nairobi

Sampling Point	CO_2 (ppm)	CO (ppm)	NO_x (ppm)	Temperature (°C)	Wind Velocity (m/s)
UWR	622.25±32.94	12.26±0.32	2.44±0.26	26.90	1.65±0.20
FSR	660.00±15.46	12.56±0.16	2.56±0.34	27.90	1.60±0.23
HSR	627.00±13.76	12.56±0.26	2.50±0.38	28.20	1.46±0.09
NHR	613.50±14.37	12.44±0.91	2.62±0.45	25.60	1.68±0.26
GCR	655.50±25.57	13.60±0.69	3.02±0.69	28.40	1.59±0.19
KBS	646.25±33.02	13.63±0.46	3.02±0.97	26.90	1.29±0.18
BBR	605.50±28.49	12.35±0.59	2.47±0.41	27.80	1.94±0.11
JMK	614.50±24.49	12.38±0.48	1.52±0.33	27.70	1.73±0.14
JTR	675.25±21.20	12.56±0.81	2.47±0.34	31.80	1.58±0.20
WMR	628.25±22.04	13.05±0.42	3.02±0.26	25.30	1.61±0.20
Mean	**634.80±23.13**	**12.74±0.51**	**2.56±0.44**	**27.65**	**1.61±0.18**

UWR- University Way Round About, FSR- Fire Station Round About, HSR- Harambee Sacco Round About, NHR- Nyayo House Round About, GCR- Globe Cinema Round About, KBS- Kencom bus stage, BBR- Bomb Blast round about, JMK- junction of Muhindi Bingu and Kenyatta Avenue, JTR – junction of Tom Mboya and Ronald Ngala Street, WMR –Wakulima Market round about

The null and alternative hypotheses were considered for the gases sampled as shown in Table 3.

Table 3: Representation of hypotheses

	Pollutant	Mean (ppm)	Null Hypothesis	Alternative Hypothesis
1.	CO_2	**634.80**	$H_o : \mu \leq 5000$ ppm	$H_a : \mu > 5000$ ppm
2.	CO	**12.74**	$H_o : \mu \leq 50$ ppm	$H_a : \mu > 50$ ppm
3.	NO_X	**2.56**	$H_o : \mu \leq 3$ ppm	$H_a : \mu > 3$ ppm

The hypotheses were tested for the sampled pollutants applying *'t'*- test at 5% significant level. A summary of the results are presented in Table 4.

Table 4: Summary of the analyses of the hypotheses for automobile emissions

	Sample	Critical value of *'t' (One tailed)*	Df	Rejection region *(One tailed)*	Calculated value of $\mid t_c \mid$
1.	CO_2	1.833	9	R : $t > 1.833$	566.1
2.	CO	1.833	9	R : $t > 1.833$	219.9
3.	NO_X	1.833	9	R : $t > 1.833$	3

The results in Table 4 show a statically significant difference between the sample means and the population means. Thus the null hypothesis was rejected and the alternative hypothesis was therefore accepted that the automobile emission levels were above the occupational exposure limit – control limit (Long team). These results suggest that the traffic police were exposed to levels above the recommended limits and therefore were at risk of being affected by the pollutants. These findings are comparable with the findings of Atimtay *et al.*, (2000); Volpino *et al.*, (2004) and Jinsart *et al.*, (2002).

Bivariate analyses were also conducted on the parameters of air sampled by determining Pearson's Coefficient of Correlation. A summary of the results are shown in Table 5.

Table 5: Summary of Pearson's Coefficient of correlation between CO_2, CO NO_x with temperature and wind velocity

Sample	N	r_{xy} (Temperature)	r_{xy} (Wind velocity)
CO_2	10	0.511	-0.745
CO	10	-0.123	-0.767
NO_x	10	-0.210	-0.480

The results in Table 5 show a fairly moderate degree of positive correlation (r_{xy} = 0.511) between CO_2 with temperature while a weak negative correlation between CO (r_{xy} = -0.123) and NO_x (r_{xy} = -0.210) with temperature was observed respectively. This perhaps shows the important role played by NO_x in the formation of O_3 at elevated temperatures. This agrees with the results of Odhiambo *et al.,* (2010) who in their study demonstrated that there existed a positive correlation of O_3 with temperature (r_{xy} = 0.66) with a diurnal cycle for O_3 and NO_x being observed in the mid day and most parts of the afternoon. Odhiambo *et al.* (2010) were able to demonstrate that O_3 increased with a decrease in the concentration of NO. Odhiambo *et al.* (2010) further observed that there was a high correlation between NO and vehicle density (r_{xy} = 0.94) and concluded that motor vehicle exhaust contributed to high proportions of NO. The positive correlation between CO_2 (r_{xy} = 0.511) with temperature and the negative correlation between CO (r_{xy} = -0.123) with temperature suggests that temperate also plays a critical role in the combustion process. The amount of CO produced is therefore a good indicator of the combustion efficiency of the engine since in any combustion process CO_2 and water must be produced as by products. Additionally the results showed a fairly high degree of negative correlation between CO_2 (r_{xy} = -0.745) and CO (r_{xy} = -0.767) with wind velocity while a moderate negative correlation between NO_x (r_{xy} = -0.480) with wind velocity was observed. These results further revealed that the highest concentrations of the pollutants were obtained when the wind speeds were lower. These results compare well with the results that were obtained by Odhiambo *et al.,* (2010), when they demonstrated that higher O_3 concentrations were observed during lower wind speeds. This implied that wind plays a crucial role in the dilution of the pollutants once emitted from the source and therefore at lower wind speed dilution of the pollutants is retarded as the transportation of pollutants away from the point of emission is reduced. However, other probable factors that affects wind velocity include the development of high rise structures within the Central Business District and pressure differences prevailing at any one time (Bell, 2006).

3.2 Period of Exposure

A study carried out by Bell, (2006), demonstrated that the health effects of any pollutant in an individual is directly dependent on the exposure period and toxicity of the pollutant. In this study therefore, the period of exposure by the TPO's as they discharge their duties on the road was determined and the results were as detailed in Figure 2.

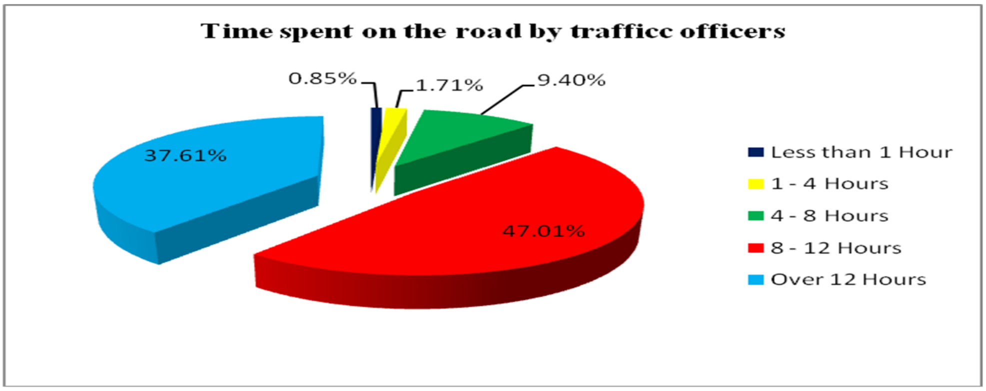

Figure 2: Period spent on the road by TPO's

The results above show that 99 (84.62%) TPO's studied spent the mandatory eight hours or more on the road while only 18 (11.96%) spent 8 hours or less while discharging their duties. The average hours spent on the road was 10 hours. Ideally there are two shifts of eight hours each for the traffic police officers who work in the Central Business District. The morning shift starts at 6.00 am and end at 2.00 pm while the afternoon shift commences at 2.00 pm and ends at 10.00 pm. However, when an officer falls sick or has to leave because of other reasons, his or her duties must be taken over by other officers. But because of the limited number of officers, at times one repeats a shift. This fact was illustrated when a majority of TPO's stated that they spent more than twelve hours on the road while discharging their duties within the Central Business District. Other factors that require TPO's to spend more time on the road included increased human traffic and non-operational traffic lights within the Central Business District. The officers have to be physically present to control the traffic both humans and vehicles in the Central Business District. It is also worth noting that a few of the operational traffic lights in the Central Business District are rarely followed by road users. These results suggest that a majority 99 (84.62%) of the TPO's were exposed for long periods on daily basis. This coupled with the high concentrations levels of the pollutants as already discussed above predisposes the TPO's to the effects of automobile air pollution. This therefore provides credible evidence suggesting that the TOP's were at risk of being affected by the pollutants. These results are comparable with other studies previously carried out by Peters *et al.,* (1999); Zemp *et al.*, (1999); Nanda Kumar *et al.,* (2009); Gauderman *et al.,* (2000); WHO, 2002; Finkelstein *et al.,* (2004); Bell, 2006 and Michael *et al.,* (2008).

3.3 Effects of Automobile Pollution on the Health of the TPO's

Questionnaire analysis of the responses of the TPO's on the effects of exposure to automobile emissions are presented in Table 6.

Table 6: Effects of automobile polution on the health of TPO's

Score	Frequency	Percent	Remarks
40 to 65	103	88.0%	Favourable
39	12	10.3%	Neutral
< 39	2	1.7%	unfavourable
Total	**117**	**100.0%**	

The results in Table 6 show that 103 (88%) of the TPO's reported to have been affected by the pollutants in their work environment. This was followed by 12 (10%) of the TPO's who reported a neutral position while only 2 (2%) TPO's reported that they were not affected. The two included the TPO's in the two station who exercised supervisiory duties and spend most of their time in the office. The officers mainly compained of sneezing, flue, irritation of the throat, nose, eyes and lungs. These results are comparable to the findings of Proietti *et al.*, (2005).

4.0 Conclusions and Recommendations

In conclusion, this study has revealed that the TPO's were exposed to automobile CO_2, CO and NO_x emissions levels that were above the recommended OEL –CL and WHO recommended values. It is therefore, highly probable that continued exposure of the TPO's to these toxins is likely to lead to adverse health effects in the future. It is recommended that priority be given to preventive measures including monitoring fuel quality, instituting controls on vehicle age and reduction of access to Central Business District in major towns, establishing and enforcing air quality standards that are in line with WHO air quality guidelines. Finally, further study may be considered that incorporates medical examinations or biological monitoring to determine the cause effect relationship of each specific pollutant.

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