# IMPACT OF URBAN TRAFFIC ON THE AMBIENT AIR QUALITY IN FREETOWN

**ENVIRONMENT PROTECTION AGENCY**

**SIERRA LEONE (EPA-SL)**

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## Executive Summary

The overarching goal of the Environment Protection Agency Sierra Leone (EPA-SL) is to protect the environment of Sierra Leone. One of the prime functions of EPA-SL is to establish various pollution index standards in the different media. It was against this backdrop that this piece of work was initiated to study the impact of vehicular traffic on the ambient air quality along a single carriage road on one side (Kissy Road) and dual carriage road (Wilkinson Road). Brief monitoring of air quality indices-nitrogen dioxide ($NO_2$); sulphur dioxide ($SO_2$) and carbon monoxide (CO) were made between August 2015 and September 2015 using the Drager X am 5000 realtime monitor for the different gases. Diurnal monitoring was made in the morning, afternoon and evening periods representing peak and off peak periods. Meteorological variables were noted as well as traffic density for the two sites. Results indicated that higher levels of pollution episode were captured at Kissy Road relative to Wilkinson Road for the different indices suggesting that the local air shed at this site was greatly impacted by air pollution. Considerable variation were also observed among the pollutants for the two sites and the hourly peak values revealed astonishingly high levels that could be considered unacceptable, when compared with the USEPA ambient air quality standards. The implications to such remarkable peak values cannot be overlooked given that the range of traffic speed was noted to be 5-15 km/h and 15-40 km/h for Kissy Road and Wilkinson Road, respectively. Field observations noted that poorly maintained vehicles, human behavioral pattern and frequent traffic jams were strongly attributed to the observed values. It is however suggested that the EPA-SL should engage and collaborate with stakeholders such as Sierra Leone Roads and Safety Authority, Meteorological Department of Sierra Leone, Ministry of Works, Ministry of Transport and Communication, Ministry of Health and Sanitation, Sierra Leone Standards Bureau, Dealers of Imported Fuels *etc* to coordinate efforts that would embark on a long term monitoring plan of key indices of air pollution. Furthermore, EPA-SL should have their presence at the metrology and quality control departments of the Sierra Leone Standards Bureau so as to reinforce the quality of imported fuels as this present study revealed strong evidence of sulphur compounds in the atmosphere. It is again advised that EPA-SL should liaise and coordinate efforts with Sierra Leone Road Safety Authority to develop a robust scheme for routine vehicle emission checks and minimum standard of all imported vehicles. There is an urgent need to formulate urban transport system in Freetown and other big cities. An exposure-response study for vulnerable groups is strongly recommended.

## 1.0 Introduction

The releases of acidic pollutants (e.g. sulphur dioxide and nitrogen dioxide) in the atmosphere can cause adverse health effects and have the potential to cause other environmental damage (Lee et al., 1999). They can be released by either anthropogenic or natural sources and they can undergo several transformations as a result of the complex reactions in the atmosphere (e.g. gas to particle conversion, transport associated with wind and wet and dry deposition). Vehicular traffic is a major source of combustible gases emissions in cities of developing countries. Previous studies in developing countries have shown that air pollution in urban areas are the result of vehicular emissions (Jackson, 2005; Fanou et al., 2006; Jenny et al., 2008; Dionisio et al., 2010; Kandasamy et al., 2011; Olajire et al., 2011; Taylor & Nakai, 2012). It has also been recently reported in Nigeria that about 60% of urban air pollution in mega cities such as Lagos is due to emissions from vehicles (Abam & Unachukwu, 2009; Hopkins et al., 2009) makes air pollution due to traffic worrisome particularly in developing countries where more than 80% of vehicles are in a very bad shape. This problem would be further exacerbated where there is lack of effective policy instruments that addresses urban transport systems, land use planning and the growing ownership of vehicles and traffic congestion. According to a recent UN report (UNEP, 2010), rural population of developing countries will continue to migrate to urban areas or cities of developing countries in search of better lives. As a consequence, if nothing is done, this urbanization pattern will further worsen the serious air quality problems in sub-Saharan African cities with further direct consequence on human health.

Outdoor air pollution is no longer seen as a major problem for developed countries but now a major problem in developing countries. The World Health Organization has noted that large cities of developing countries have a poor air quality thereby exposing huge number of people to ambient levels of air pollutants that are above WHO guidelines (WHO, 2000). Of great concern are the large number of pedestrian and street sellers mostly women and children who are exposed to noxious exhaust fumes. Several epidemiological studies have revealed association between exposure to traffic generated air pollutants and health endpoints such as asthma, respiratory problems, cardiovascular diseases, cancer among children, elderly and women (Peters et al., 2001; Abu-Allaban et al., 2002; Lee et al., 2002; Lin et al., 2002; Yang et al., 2004; Peel et al., 2005; Lanki et al., 2006).

Freetown, the capital of Sierra Leone is confronted with a number of environmental and public health concerns. One notable area is the ambient air environment. The problem of outdoor air pollution is pervasive and a combination of conventional sources is quite pervasive. Among these, traffic source of air pollution is one of the major contributors to the problem in urban areas. Nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$) and carbon monoxide (CO) are usually indices of traffic air pollution. In many developing countries as the case of Sierra Leone, single and dual carriage roads are quite apparent. It is undoubtedly clear that over 90% of automobiles in Freetown are used second hand vehicles that ply these roads with engines that combust unregulated gasoline and diesel fuels. A clear impact is the visible plumes of smoke from vehicle tail pipes and this has been echoed in a recent study conducted in Freetown (Taylor & Nakai, 2012). Knowledge of the contribution of traffic related indices of ambient air pollution is necessary to evolve a proper strategy to control and mitigate the problem. However, the absence of periodic monitoring data that would through light to the environmental state and the potential health implications remain a big challenge in Sierra Leone. This study therefore focuses on:

- measuring common air quality indicators ($NO_2$, $SO_2$ and CO) along a single and dual carriage urban roads in Freetown;
- quantifying traffic density for automobiles at the respective road sites in Freetown;
- obtaining meteorological information for greater Freetown during the measurement period and;
- identifying management strategies to mitigate impact.

From the "*agenda for change*" setting that was proposed by the government of Sierra Leone in 2007, emerged the Environment Protection Agency of Sierra Leone (EPA-SL, 2008). The overarching goal of the EPA-SL is to protect the environment of Sierra Leone. Among the several mandates of EPA-SL includes but are not limited to developing environmental policies in areas as diverse as air quality, ozone depletion and climate change, water quality, environmental impact assessment guidelines, prudent extractive industries agreement, setting up environmental standards for key environmental indicators, foster research to set limits, assess the fate of pollutants in ecosystem, land use preservation *etc*. Baseline information to support much urgent needed policies is often not available. At present the agency is embarking on a long journey to setting up standards for indices of the different media for which this pilot study is envisaged to provide further information about the problem of air pollution. It is envisaged that this study would present a window of opportunity to engage local stakeholders to understand air pollution issues from local perspective with the drive to formulate national policies centered on managing the problem ambient air pollution.

## 2.0 Materials and methods

*2.1 Study Area*:

This study was conducted in Freetown, founded on the 11th March 1792. It was selected for the study because it is the capital city of Sierra Leone where more than half of automobiles in the country exist. It is a Port city that is 27 m above sea level and lie on coordinates 8.48°N and 13.23°W with a total area of 137.8 square miles (357 square kilometers) located on the western area of the country on a mountain peninsula stretching into the Atlantic Ocean. The climate of Sierra Leone is tropical (hot and humid); with the raining season lasting from May to December and the dry season from December to April. Rainfall along the coast can reach 495 cm a year with Freetown having the highest amount of rainfall, greater than 3500 milliliters. The current population is estimated to be more than one million. The city is politically divided into three broad regions-East, Central and West.

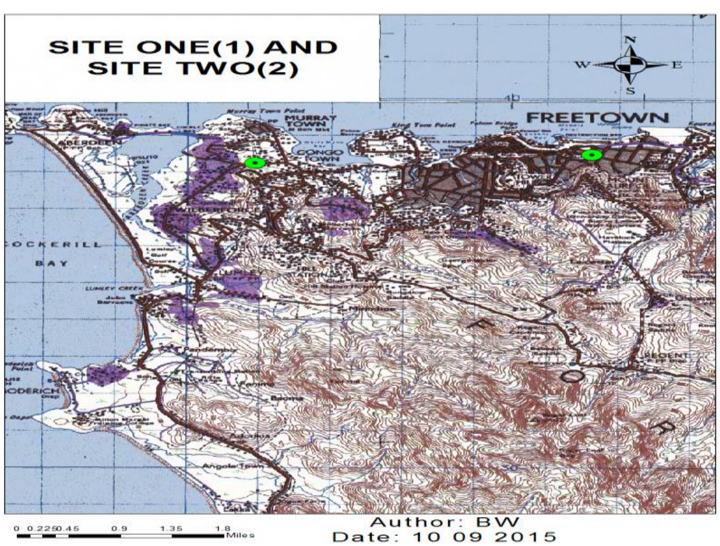



**Figure 1**. Map of the study area showing the two monitoring sites

*2.2 Sites description*

*Kissy Road - Site 1*: This site is a single carriage road that is situated in the East end of the city linking the peripheral or sub urban areas to the city center. This site represent the main entry point for office workers residing in the East end and hence subject to slow traffic with speed of 5-15 km/h for most part of the day. Heavy vehicles usually over 4 tons often ply this route to the city center conveying imported goods to the marketing stalls. Traffic jams are quite apparent due to these heavy vehicles that often breakdown along the main road giving rise to endless queue of traffic. Commercial activities are quite apparent along the narrow strip of pedestrian path. Evidently are fairly high rising buildings that are less than 2-3 m away from the roadside depending on the area. Such attribute results in poor dispersion and mixing of air with a naturally tendency of sustaining pollutants. Average traffic density for vehicles was recorded at 320/h. There is no established system for continuous air quality control in the city which makes this pilot study very timely.

*Wilkinson Road – Site 2*: Situated in the West end of the city, this road was recently expanded and upgraded to dual carriage capacity so as to ease the traffic congestion from the West end. Due to the enhanced capacity, traffic flow was recorded to be 10-40 km/h and the stretch of this road is mostly being influenced by the Atlantic Ocean which is just about less than 150 m in some areas. It is an area where pollutants can be easily dispersed as most buildings are quite spacious which allows mixing of air and sea breeze influence.


**Figure 2**.Collection of field data and traffic flow

*2.3 Equipment and Monitoring program*

The Drager X- am 5000 (*www.drager.com*) was used for the monitoring program which was obtained from Ribble -Enviro Ltd UK in August 2015. It is a small, light and easy to use which makes it very ideal for field monitoring in areas where conventional monitoring requirements are somehow restricted. It is very robust, water-tight and is designed for single-handed operation in tough industrial environments. Water- and dustproof according to IP 67 and with an integrated rubber boot, the device provides optimal functionality even under harsh conditions. This monitor measures up to six gases simultaneously and for the purpose of this study, four electrochemical infrared sensors for $CH_4$, $NO_2$, $SO_2$ and CO were used for this study. The device has a high resolution of 0.1 ppm for both $NO_2$ and $SO_2$ and 2 ppm for CO with a very short response time of 15 seconds for both $NO_2$ and $SO_2$ and 25 seconds for CO.


**Figure 3**. The Drager X am 5000 portable monitoring device for $NO_2$, $SO_2$ and CO gases

The monitoring exercise was done between 18th August 2015 and 6th September 2015 during the raining season along the roadside of each of the monitoring site earlier described. A monitoring distance of 1.5 m from the edge of the road and a height of 1 m were selected. Two field Assistants were trained to monitor roadside levels along pedestrian pathways where they stood and undergone hourly shift duty so as to ease the stress and risk of roadside exposure. Values were recorded on a record sheet by field Assistants. Daytime monitoring was made between the hours of 7:30 GMT and 19:30 GMT each day for a period of three weeks on an alternate day. The peak periods were noted from 7:30 GMT to 9:30 GMT which is considered as morning rush hour; 17:00 GMT to 19:00 GMT as evening rush hour but off peak period was taken from 12:30 GMT to 14:30 GMT each day monitoring was made.

**Figure 4**. Images showing field assistants recording values of ambient air indicators

*2.4 Quality Control Procedure*

The zero point accuracy of the sensors was reached by carrying out the fresh air calibration each time measurement was made. This was achieved by the 1 button calibration procedure in an area away from monitoring zone or area where trace levels of the measured gases or interfering gases are found. Field assistants had to move to the middle of nearby secondary school campuses where there is little evidence of ambient air pollution to carryout fresh air calibration, and the display containing the current gas concentration changes with the display OK when calibration was done indicating a successful calibration process.

*2.5 Records of Traffic Density:*

The traffic volume survey was conducted each day monitoring was made and both larger vehicles (those exceeding 3.0 tons) and smaller vehicles such as sedans, pick up and minivans or minibuses were considered. Hourly records were taken by counting the number of vehicles in fifteen (15 minutes). This value was however equated to one hour to get the hourly average.

Table 1. Hourly traffic density for automobiles along the two monitoring sites in Freetown.

| **SITE 1** | | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | Afternoon | | Evening | |
| | 1st hr | 2nd hr | 1st hr | 2nd hr | 1st hr | 2nd hr |
| Day 1 | 302 | 315 | 280 | 265 | 345 | 370 |
| Day 2 | 324 | 340 | 456 | 424 | 240 | 255 |
| Day 3 | 420 | 398 | 252 | 262 | 220 | 235 |
| Day 4 | 468 | 420 | 444 | 425 | 528 | 496 |
| Day 5 | 415 | 402 | 260 | 255 | 235 | 255 |
| Mean | **386** | **375** | **338** | **326** | **274** | **322** |
| St Dev | **70** | **45** | **102** | **89** | **184** | **110** |
| | | | | | | |
| **SITE 2** | | | | | | |
| | Morning | | Afternoon | | Evening | |
| Day 6 | 960 | 1020 | 1176 | 1260 | 840 | 865 |
| Day 7 | 900 | 960 | 708 | 750 | 1056 | 1090 |
| Day 8 | 600 | 680 | 936 | 1028 | 1104 | 1060 |
| Day 9 | 696 | 725 | 588 | 640 | 888 | 902 |
| Day 10 | 610 | 690 | 946 | 1038 | 1116 | 1050 |
| Mean | **753** | **815** | **870** | **943** | **1001** | **993** |
| St Dev | **167** | **162** | **228** | **247** | **128** | **102** |

Morning rush hour period was taken from 7:30 to 9:30 GMT
Afternoon period was taken from 13:00 to 15:00 GMT
Evening rush hour was taken from 17:00 to 19:00 GMT

*2.6 Records of Meteorological Variables*:

Details of meteorological parameters such as temperature, rainfall, humidity, wind speed and direction were meant to be obtained from the Sierra Leone Meteorological Department in the Ministry of Transport and Communication. However, it was quite disappointing to note from such an important office that records for Freetown were not available except for Lungi and Mamammah. Therefore, meteorological variables were obtained from a Met forecasting website as indicated in **Table 2**.

**Table 2**. Meteorological variables during the study period (August 2015 to September 2015)**.**

| | Rainfall Probability (%) | Temperature (°F) | Relative. Humidity (%) | Wind direction | Wind speed (mph) |
|---|---|---|---|---|---|
| | | | | | |
| Day 1 | 60 | 84 | 89 | SW | 5 |
| Day 2 | 50 | 82 | 92 | WSW | 7 |
| Day 3 | 45 | 82 | 85 | WSW | 4 |
| Day 4 | 40 | 82 | 85 | S | 9 |
| Day 5 | 90 | 83 | 95 | SW | 5 |
| Day 6 | 85 | 84 | 90 | WSW | 8 |
| Day 7 | 65 | 82 | 85 | S | 3 |
| Day 8 | 50 | 81 | 88 | W | 5 |
| Day 9 | 82 | 81 | 90 | WSW | 8 |
| Day 10 | 96 | 80 | 96 | SW | 6 |

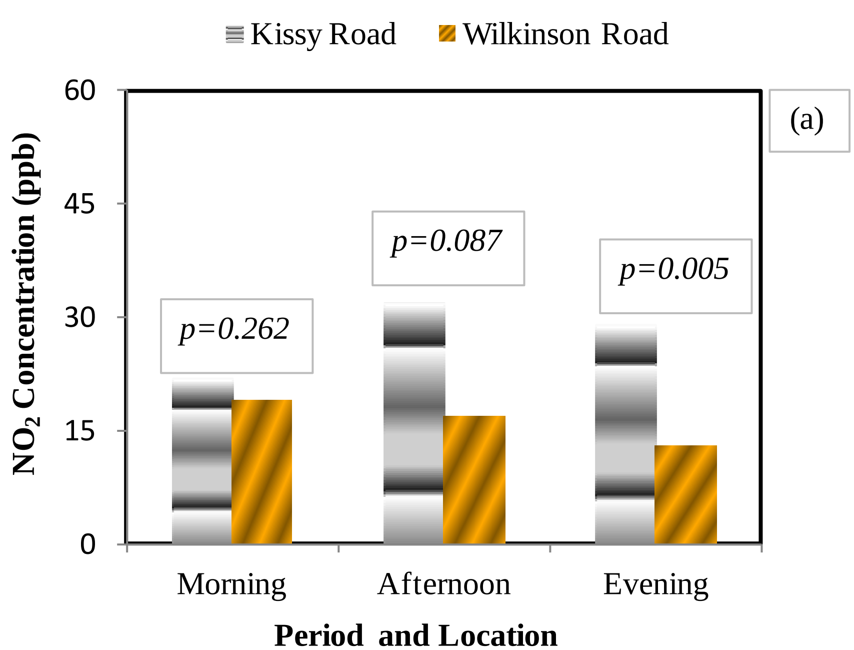
Meteorological variables have been reported from: http://www.weather.com/weather/tenday/l/Freetown+Sierra+Leone+SLXX0001:1:SL . Worth noting was that the met data for Freetown should have been recorded and produced by the Sierra Leone Meteorological Department of Charlotte Street. However, it was revealed that data from the met monitoring station at Fourah Bay College could not be produced due to a missing cord that transmits raw data into realtime output. The monitoring period was between 18th August 2015 and 6th September 2015.

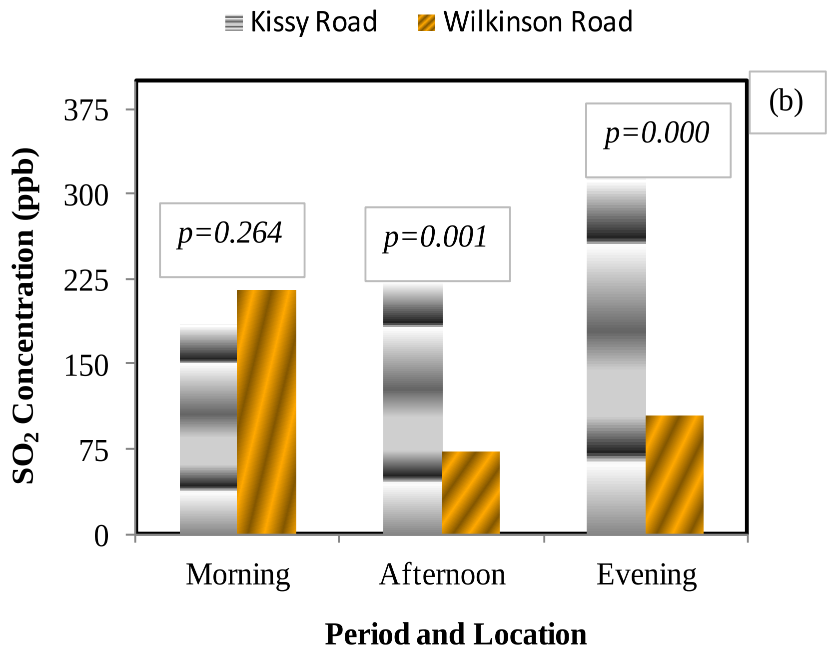
*2.7 Data Analysis*

Quantitative and numeric data were obtained from the study; hence data were subjected to descriptive statistics. Hourly vehicle count was done when a fifteen minute counting period elapse. Average values for numeric meteorological variables were tabulated and the prevailing condition for descriptive meteorological were computed. The relationship among air quality indicators were analyzed so as to determine whether they are coming from the same source or having a similar origin. The association between traffic density and air quality indices was done to identify source influence, if any. t-test was used to compare mean concentrations for $NO_2$, $SO_2$ and CO between peak and off peak periods. Since the data did not follow a normal distribution pattern, a Wilcoxon non parametric test was used to test whether group means are similar across groups ($NO_2$, $SO_2$ and CO). A threshold value of significance (*p value*) was taken at 5% or 0.05 from which all statistical inferences were made. These analyses were conducted using JMP 8 statistical package. Results are presented in the form of charts and graphs.

## 3.0 Results and discussion

This pilot study was undertaken to understand the spatial distribution and current trend of combustible gases along a single carriage road and dual carriage road in Freetown. Three distinct periods representing morning peak, afternoon and evening peak were monitored for $NO_2$, $SO_2$ and CO gases. The preliminary results showed that concentration levels at the single carriage roads were relatively higher than those at the dual carriage roads. According to **Figure 5 (a)**, it was revealed that there is a significantly higher level of $NO_2$ in the evening hours at Kissy road relative to Wilkinson Road but no such difference in the level of $NO_2$ was observed in the morning period. In the same way, the spatial distribution of $SO_2$ levels between the two sites appeared to be the same in the morning period but a significantly high level of $SO_2$ was recorded at Kissy Road in the afternoon and evening hours as evident in **Figure 5 (b)**. From **Figure 5 (c)**, it was observed that there is a marked variation of CO between the sites. Higher levels of CO were observed in the afternoon and evening periods at Kissy Road relative to Wilkinson Road but this pattern appeared to change in the morning period.





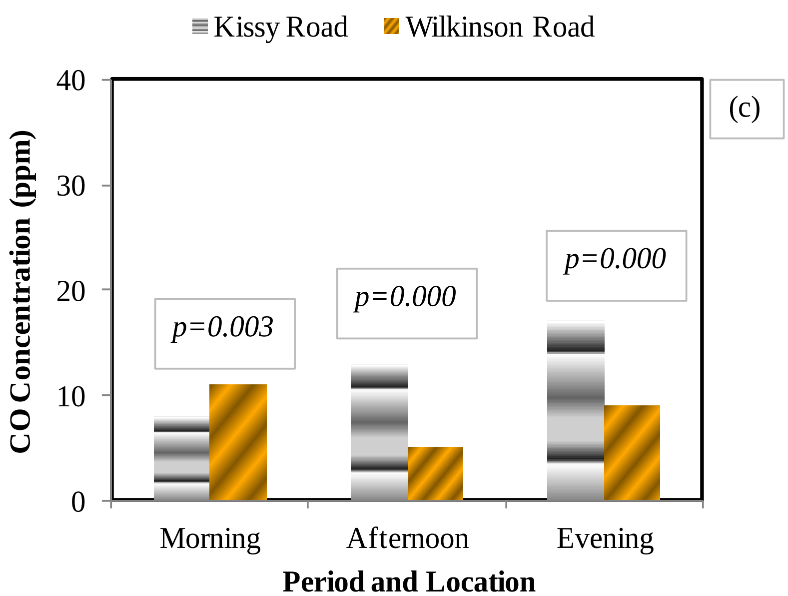




**Figure 5**. Spatial distributions of air pollutants across the monitoring sites for (a) $NO_2$ concentrations (b) $SO_2$ concentrations and (c) CO concentrations.

The level, location and duration of pollutant concentration within a region depend on plume height, wind speed, rate of vertical mixing in the atmosphere and distance from source (Naja & Lal, 1996). Hence, the vertical mixing of pollutants in the atmosphere might have resulted for the relatively higher levels at Kissy Road to Wilkinson Road. Even though there was higher traffic flow at Wilkinson Road relative to Kissy Road per hour, yet levels were higher in Kissy Road. This observation contravenes a previous study in Tanzania where higher levels were observed at roadside where vehicular counts are higher (Jackson, 2005).

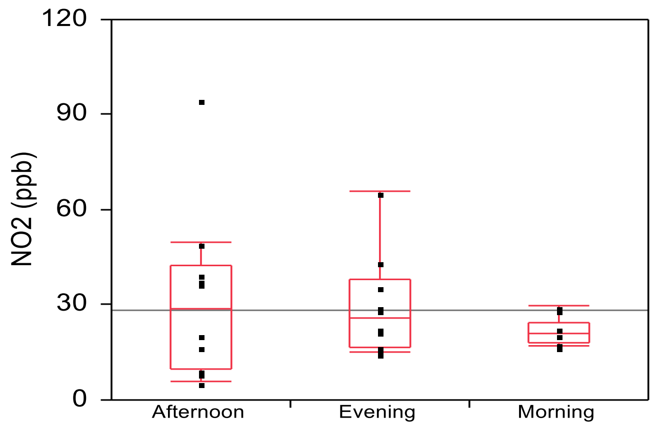



**Figure 6 (a)**: Box plots showing hourly variation of $NO_2$ for the monitoring periods at Kissy Road ***p=0.745***

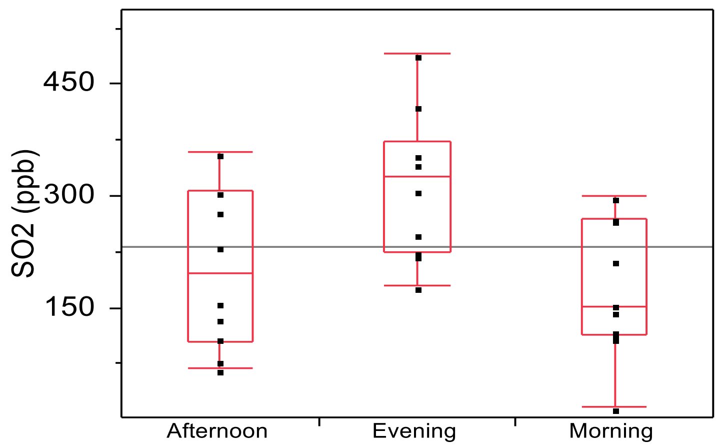



**Figure 6 (b)**: Box plots showing hourly variation of $SO_2$ for the monitoring periods at Kissy Road ***p=0.0145***

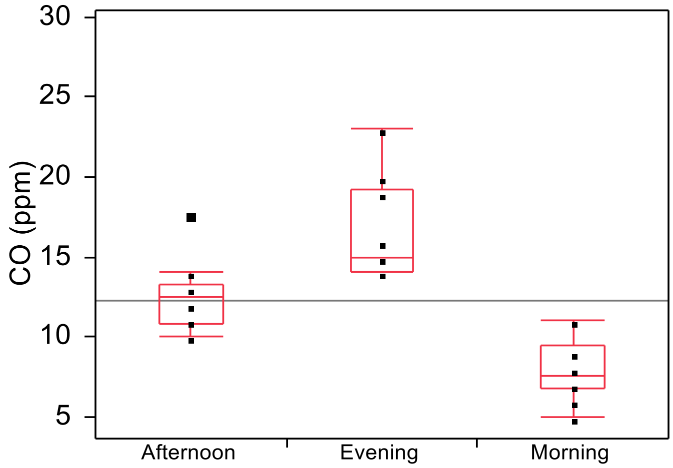



**Figure 6** (**c**): Box plots showing hourly variation of CO for the monitoring periods at Kissy Road ***p=0.0001***

There is no significant variation in $NO_2$ levels during the day as observed in Figure 6 (a) which goes to suggest that emission of $NO_2$ seem to be constant or an indication that human exposure to $NO_2$ might be similar. On the contrary, however, there seem to be an apparent and significant variation of $SO_2$ and CO levels during the day as observed in **Figure 6 (b)** and **(c)**, an indication that emission sources vary quite considerably.

Since our data were collected for just three weeks in August and September 2015, it is of interest to know how this study compares to other studies in developing countries. A study that was conducted along a major road in Lagos, Nigeria (Olajire et al., 2011) showed higher levels of CO relative to the average reported in this study. However, the CO level reported in the evening period at Kissy Road is comparable with the referred study. This suggests as observed in the traffic congestion along Kissy Road that traffic problems are quite apparent and severe. Results for $SO_2$ for the same study in Nigeria revealed high level of $SO_2$ which could be compared with that reported in this study even though results are reported in $\mu g/m^3$. For $NO_2$, the levels reported in the same study in Nigeria appeared to be same as this goes to support evidence from WHO that $NO_2$ is on the decline globally in urban areas. In another study looking at the spatial distribution of CO in Ouagadougou Burkinafaso (Jenny et al., 2008), the average levels reported are lower than what the current study reported but evidences of peak CO values showed critical values that exceeded WHO and ambient air quality standards. Another study in Benin (Fanou et al., 2006) reported high levels of organic air pollutants that are confronting the urban atmosphere in Cotonou. In another study in Accra Ghana (Dionisio et al., 2010), indices of ambient air quality were largely in agreement with ambient standards and health guidelines. It must be said also that the mode of sampling were different as passive diffusion tubes were used to sample $NO_2$ and $SO_2$. Emphasis should be made on the difference of the sampling regime and mode of collection samples or monitoring procedure which would have accounted for such variations.

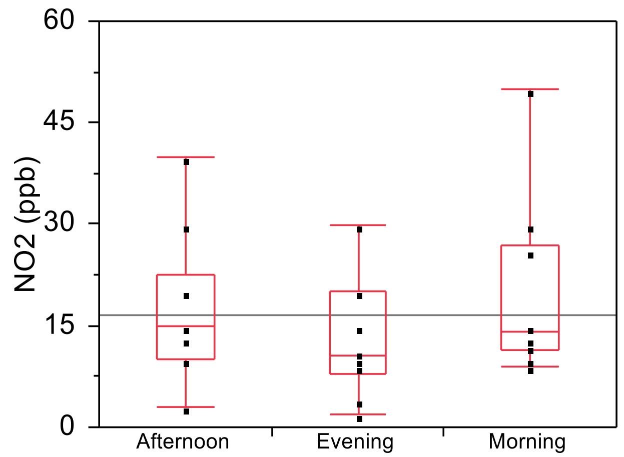



**Figure 7** (**a**): Box plots showing hourly variation of $NO_2$ for the monitoring periods at Wilkinson Road ***p=0.425***

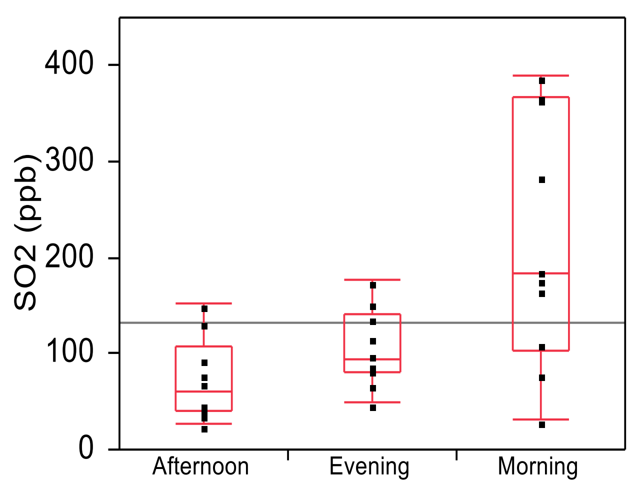



**Figure 7** (**b**): Box plots showing hourly variation of $SO_2$ for the monitoring periods at Wilkinson Road ***p=0.0001***

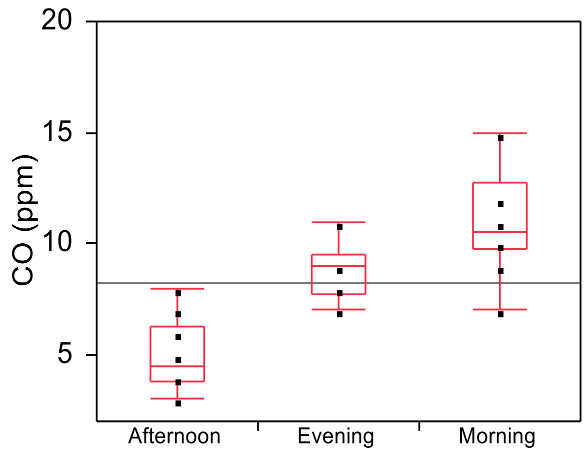



**Figure 7** (**c**): Box plots showing hourly variation of CO for the monitoring periods at Wilkinson Road ***p=0.0001***

A similar explanation given for Kissy Road site might be advanced for the observed variation of $NO_2$, $SO_2$ and CO at Wilkinson Road.

Several earlier studies have shown that pollutant concentration is highly dependent on proximity to source (Upmanis et al., 2001; Thorsson & Eliasson, 2006). These variations increase when CO-concentrations increase, and extreme situations such as traffic congestions can produce in-traffic values 20 times higher than urban background and around 6 times higher than roadside measurements.

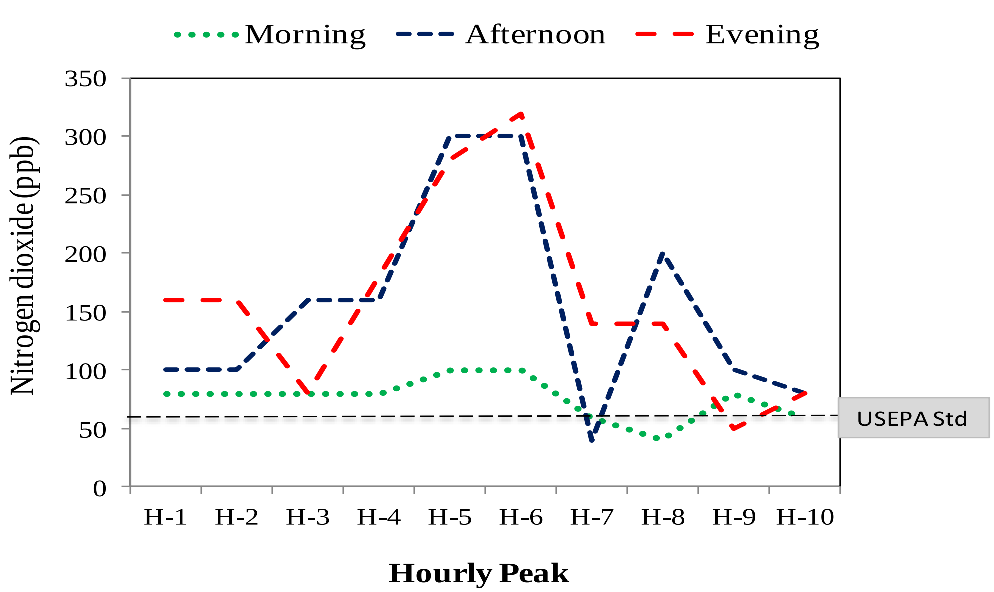



**Figure 8** (**a**): Temporal pattern of peak $NO_2$values recorded during the monitoring periods at Kissy Road.

The variance of peak $NO_2$ in the morning relative to USEPA ambient air quality standard does not vary quite significantly, unlike in the afternoon and evening as seen in Figure 6 (a).

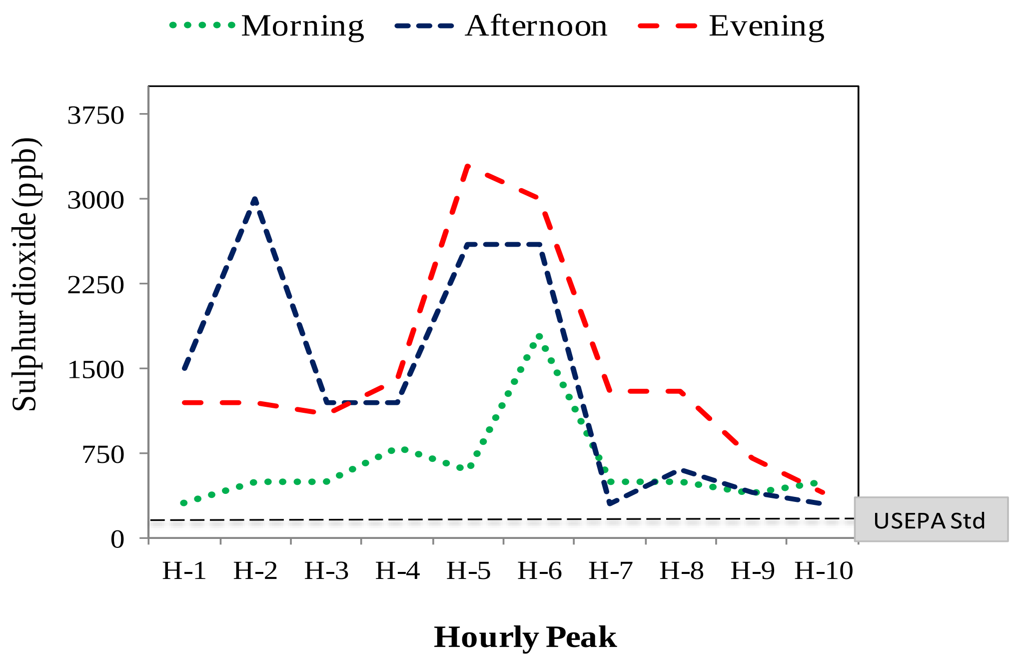



**Figure 8** (**b**): Temporal pattern of peak $SO_2$values recorded during the monitoring periods at Kissy Road

Considerable variation is quite apparent for $SO_2$ when compared with the USEPA ambient air quality standard with a noticeable deviation from the standard threshold.

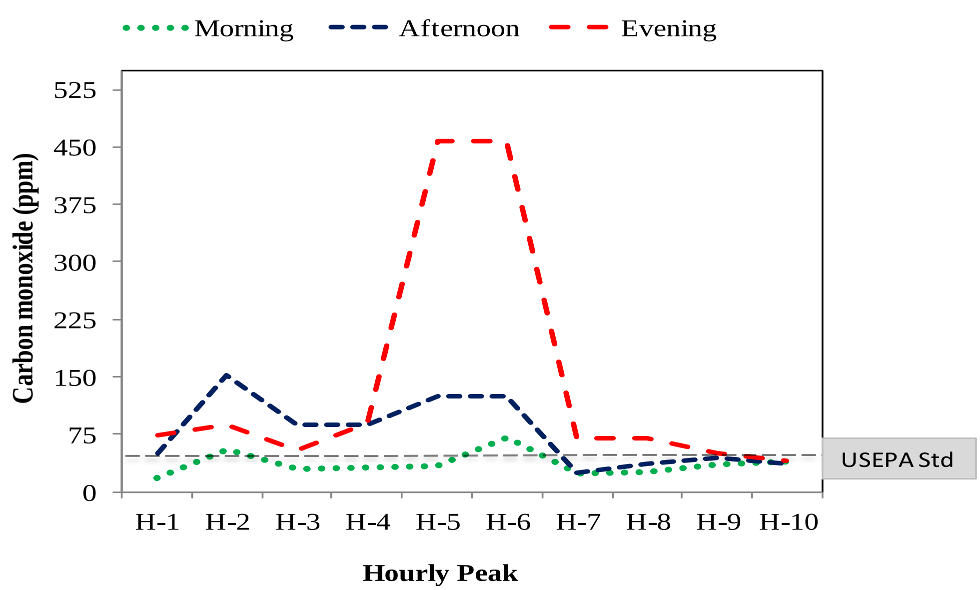


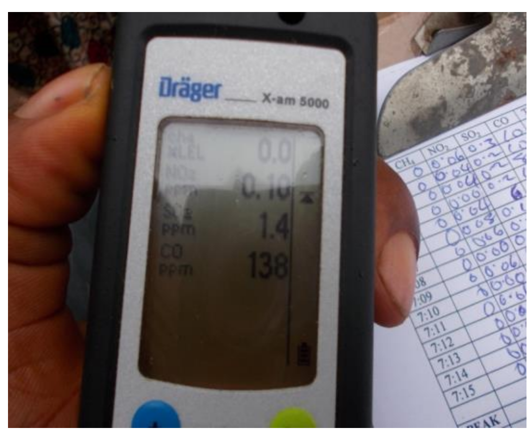
**Figure 8** (**c**): Temporal pattern of peak CO values recorded during the monitoring periods at Kissy Road

According to Figures 8 a, b and c, it could be inferred that sustained peak levels of combustible gases along Kissy Road could pose significant health risk. Consider the scenario below given that these results could not be modeled for accurate predictions.

**Pollution scenario for CO**: If the slow moving traffic is brought to a halt with high emissions from polluting vehicles at a range of concentrations of 400 ppm to 450 ppm, a buildup of traffic congestion along this route could be a quite alarming. Assume there is complete halt of about 5 minutes of traffic jam and a slow moving traffic continue at 5km/h again, the fifteen minutes average levels in that period would be in the range of 27 ppm to 30 ppm assuming no recorded levels of CO was observed. A level considered critical for sensitive receptors.

If we define the population exposed to roadside pollution as all those driving, walking or working on the street, working in buildings or living in apartments above high-traffic roads, then a large fraction of Freetown residents are expected to harmful roadway emissions on a regular basis. Another cause for the high roadway exposure across the entire population is the high concentration of informal businesses and shops on roadsides, which are frequented by lower and middle class urbanites alike.

As noted, walking is becoming the single most common mode of transport in Freetown as evident along the Kissy Road. It should be noted that people who walk do so primarily because they become very uncomfortable during traffic congestion with so much of delays moving from one point to another or the high price set by OKADAs riders. This is significant because these pedestrians are the city's poorest residents, which suggests that this already-vulnerable population group may suffer from disproportionate exposure to air pollution. Evidence and peak values of combustible gases are displayed below.


***EVIDENCE OF PEAK OR CRITICAL VALUES***

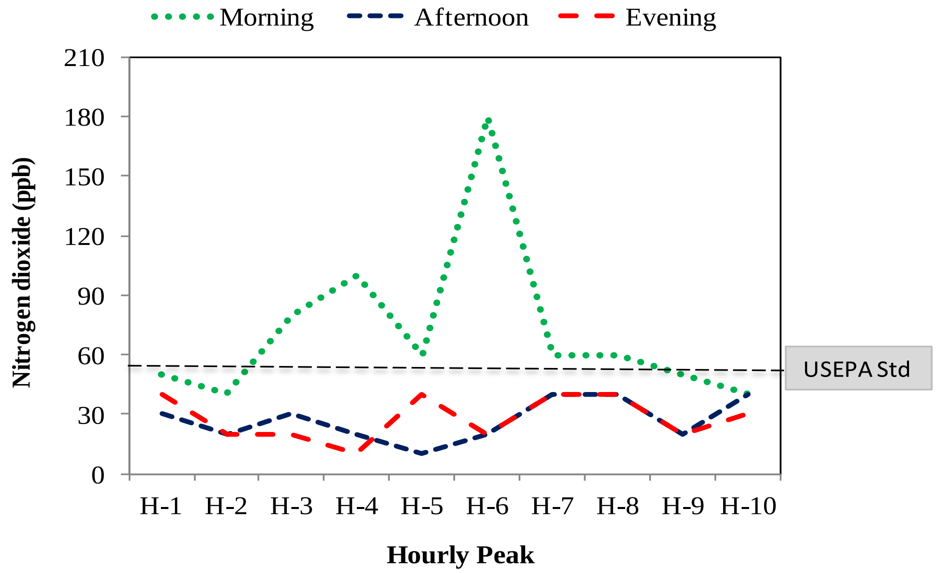



**Figure 9** (**a**): Temporal pattern of peak $NO_2$values recorded during the monitoring periods at Wilkinson Road.

There is no significant difference for $NO_2$ between the afternoon and evening periods with values well below the accepted standard.

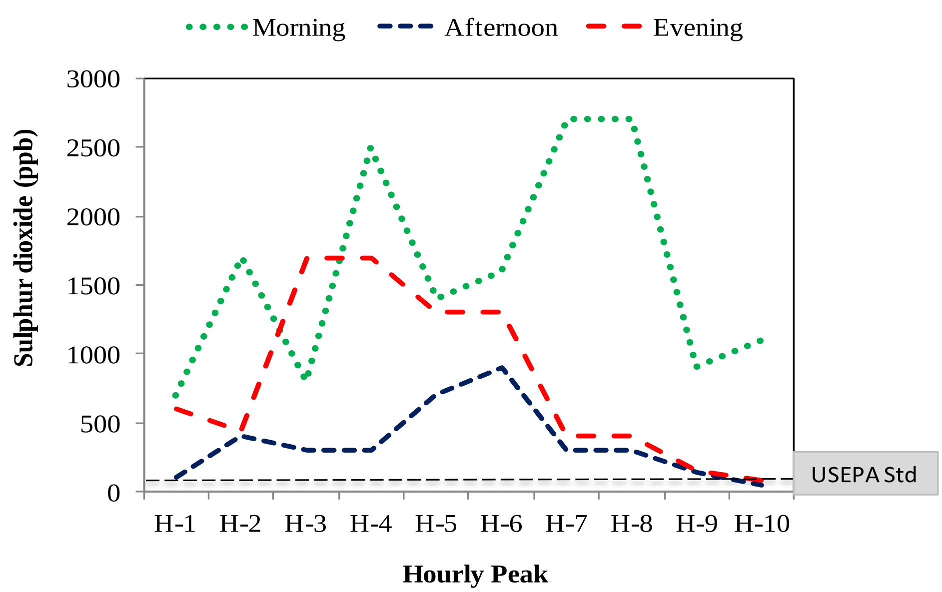



**Figure 9** (**b**): Temporal pattern of peak values recorded for $SO_2$ during the monitoring periods at Wilkinson Road

There is a high but significant variation of $SO_2$ from the accepted standard as evident in Figure 7 (**b**). It was quite interesting to note higher peak levels of $SO_2$ in the morning relative to the other periods.

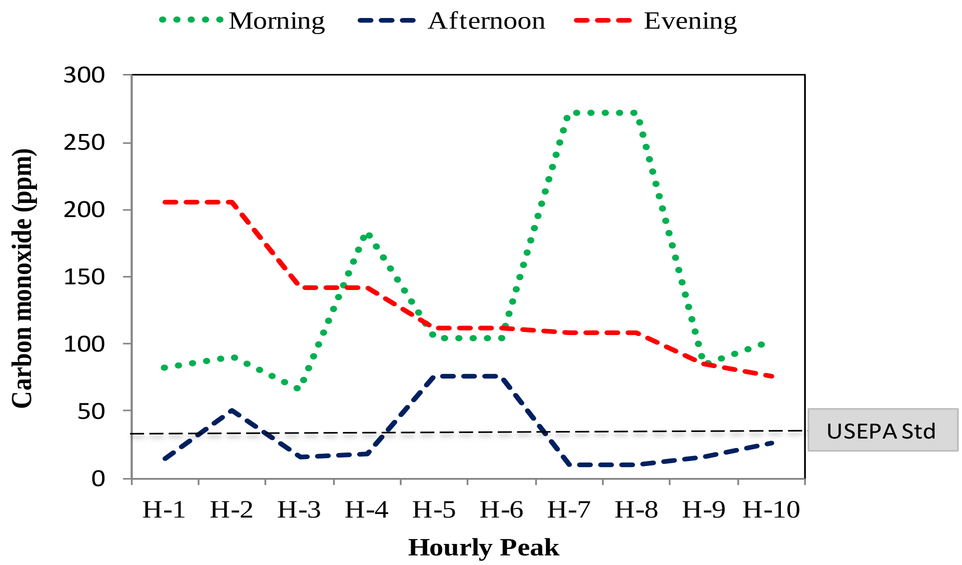



**Figure 9** (**c**): Temporal pattern of peak values recorded for CO during the monitoring periods at Wilkinson Road

**4.0 Policy Implications**

The policy implications of this pilot study are substantial.

On a metropolitan level, Freetown is growing rapidly without accompanying transportation and infrastructure services or even an urban transportation policy. The development of an Integrated Urban Transport Policy (IUTP) by the Ministry of Transport and Communication cannot be over emphasized. This lack of policy is made manifest by an urban transportation system characterized by severe congestion, high-polluting vehicles (*vehicle screening by the Sierra Leone Road Safety Authority*), lack of appropriate lanes for two stroke engines **Okadas**), lack of high quality fuels (*Sierra Leone Standards Bureau*), lack of pedestrian and bicycle lanes, lack high quality public transport options, and the visible signs of deteriorating infrastructures (pot holes). Such policy initiatives should be spearheaded by the Minister of Transport and communication in consultations with relevant stakeholders for onward submission to parliament for approval. Embedded in such policy document should contain poor quality of transport services, inappropriate modal or intersectional split, weak adherence to environmental requirements (quality of imported fuels) and the lack of an urban transport policy. Even though traffic congestion would definitely be mentioned as a key contributor to urban air pollution but at the same time measures to determine the extent of damage caused to the environment should be strongly highlighted.

Although this piece of study did not look at the impact of air pollution and health as well as the cost associated, these issues should be made clear in the policy document for discussion. Nonetheless, it is hoped that the current study would assist in highlighting health considerations in the proposed policy discussions. This is particularly critical at a time when the government of Sierra Leone is embarking on massive road expansion projects within Freetown which seem to be primarily opening up space for more cars on bigger roads.

Even as upgrading and expanding might be necessary, this alone will not solve the problems of congestion and air pollution. Los Angeles, a city that tried to build its transport system almost exclusively around freeways is a prime example of how this approach failed (Kenworthy, 1997). While congestion may initially ease, if no measures are taken to reduce demand and limit the use of automobiles through an efficient public transport system and non-motorized transport alternatives, the newly expanded and constructed roads will likely fill with cars again. This would suggest further worsening of air quality and negative health impacts.

## 5.0 Key Findings

- The local air shed at Kissy Road is significantly degraded by sulphur dioxide ($SO_2$) and carbon monoxide (CO) relative to that at Wilkinson Road;
- Slow moving traffic of about 5-15 km/h was a major cause for the relatively higher levels of the air quality indices;
- Large number of poorly maintained heavy tonnage vehicles (>3 tons) were visibly observed to be responsible for the recorded peak values;
- Although the hourly averages for $NO_2$ and CO indices did not show alarming results, indication of peak values have revealed unacceptable levels for roadside walkers or pedestrians or traffic officers or wardens;
- Evidence of significant hourly variation for $SO_2$ and CO at both Kissy and Wilkinson Roads were observed;
- There was no notable and consistent urban transport system observed for both sites;

## 6.0 Recommendations

- There should be an urgent consideration to develop urban transportation system for Freetown and other big cities across the country;
- Extended monitoring of air quality indicators ($PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$ and $O_3$) is strongly recommended across hot spots in Freetown and other big cities. This should be done in

accordance with other relevant stakeholders such as; Sierra Leone Roads and Safety Authority, Meteorological Department of Sierra Leone, Ministry of Works, Ministry of Health and Sanitation, Sierra Leone Standards Bureau, Dealers of Imported Fuels *etc* to coordinate their efforts and embark on this extended and long term monitoring;

- EPA-SL should coordinate their efforts with SLRSA to ensure that the rate of traffic flow be improved from 5-15 km/h to about 25-40 km/h along single carriage roads in Freetown. This will potentially reduce ambient air pollution significantly;
- In a manner of increasing quality assurance procedure, EPA-SL should have their presence at fuel terminals when fuel tankers docked so as to ascertain fuel quality checks in conjunction with Standards Bureau as there is strong evidence of sulphur compounds in the atmosphere;
- EPA-SL should liaise and coordinate efforts with SLRSA to develop a robust scheme for routine vehicle emission checks and minimum standard for all imported vehicles to Sierra Leone;
- EPA-SL should liaise and coordinate efforts with SLRSA, shipping companies, and truck owners to develop standard times for freight or containers deliveries. Also a temporal entry ban on all heavy duty vehicles during daytime into the city center should be considered. Such actions will reduce the frequency of breakdown especially along Kissy Road and other single carriage roads with a likely potential of increasing traffic flow;
- Need for an exposure response health study to be conducted. This is practically important as the burden of health on vulnerable group of people (traffic officers, wardens, traffic martial etc) would be understood;

## 7.0 Conclusions and Suggestion for further Study:

Measurements of ambient $NO_2$, $SO_2$ and CO were made in the morning, afternoon and evening in Freetown at single and dual carriage roads showed significant variations between the two sites. Elevated levels were observed at single carriage relative to dual carriage roads. Hourly average levels of $NO_2$ and CO did not show alarming threshold considered unacceptable but peak instantaneous levels revealed unacceptable values considered worrisome for sensitive receptors. During traffic congestions peak values can extend to an order of magnitude higher than average levels for respective pollutants. Evidence of sulphur compounds in the roadside atmosphere was present in significant amounts. High variation in average values were observed which would suggest that care must be taken in selecting measurements and sites which are crucial for correct evaluation. This study also point to the fact that care must be taken to ensure that measurements are representative for estimation of urban concentrations. However, for thorough understanding of personal exposure in both short and long term, further measurements, preferably with personal monitors, would be necessary. In a bid to develop environmental standards with high degree of reliability, a follow up study on all criteria air pollutants should be instituted across various hotspots in major cities across Sierra Leone.

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