

Assessment of Vehicular Emission in Major Roadways within Ibadan Metropolis

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ABSTRACT

The aggravation of road traffic as a result of rapid urbanisation and ineffective air quality management systems in urban centres pose a threat to public health. Air pollutants have significant adverse effect on the ecosystem. The study investigated the magnitude of air pollutants and relationship with vehicle emissions in three selected roads noted for their characteristic high traffic volume in Ibadan Metropolis. The concentration of carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxide (NO_x) and sulphur dioxide (SO₂) in the three selected locations (Beere market road, Mokola interchange, and Oyo road near the University of Ibadan Main Gate) were monitored using a Smart Sensor AS8900 model multi-gas detector and an IOT-based device setup known as the Raspberry pi 3+ B model with gas sensor add-on. The daily monitoring of emission was conducted for 24 days and results analysed using statistical methods. The average recorded pollutant emissions were below the standards set by the WHO. Pollutant emissions 21.81 ± 25.24 ppm for carbon monoxide, 411.92 ± 145.11 ppm for carbon dioxide, 0.04 ± 0.02 ppm for nitrogen oxides and 0.004 ± 0.001 ppm for sulphur dioxide. The concentration values of the pollutants varied with the traffic volume. Overall, the analysis indicated that there was no significant relationship between traffic volume and presence of pollutants in the study area. However, the regular agencies ought to further monitor traffic and other related pollutant emissions to ensure environmental safety.

1. INTRODUCTION

The aggravation of road traffic as a result of rapid urbanisation and ineffective air quality management systems in urban centres pose a threat to public health (Kateja, 2021). Air pollutants have significant adverse effect on the ecosystem. Gases and particulates resulting from anthropogenic and naturogenic processes have consequential public health impacts on the environment. Commercial, domestic and industrial activities are the common anthropogenic pollutant sources with emission from motor vehicles being a major source (Lang *et al.*, 2016). Traffic emissions are major sources of gaseous pollutants such as carbon dioxide (CO₂), carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x) and sulphur dioxide (SO₂) (Adeyanju and Manohar, 2017). The number of vehicles on the road has increased due to urban areas' rapid development, which has also increased emission of gaseous elements in the atmosphere. The total number of vehicles in Nigeria was estimated to be about 11.7 million in 2018, indicating an increase from previous years (National Bureau of Statistics Nigeria, 2018). This increase takes a toll on public health. Health effects of high levels of motor vehicle emission could be in form of allergies, cardiovascular diseases and respiratory diseases (Khandar and Kosankar, 2014; Arunkumar and Dhanakumar, 2019).

Vehicles that run on fuel don't use all of the fuel in the engine; instead, the undesirable particulates are discharged into the air as chemicals, which severely disrupts the ecology. Passenger cars, trucks, motorcycles, and other types of vehicles all contribute to vehicular pollution, but car emissions are a major cause of air pollution (Kumar *et al.*, 2021). Internal combustion engines (ICEs) produce pollutant emissions from burning fuel, and these include hydrocarbons (HC), also referred to as volatile organic compounds (VOCs) or non-methane hydrocarbons (NMHC), nitrogen oxides (NO and NO₂) combined, carbon monoxide (CO), and particulate matter with sizes less than 10 microns (PM₁₀) and less than 2.5 microns (PM_{2.5}), which includes black carbon (BC) (Winkler *et al.*, 2018).

A coordinated statutory response to environmental pollution in Nigeria was made possible by establishing the Federal Environment Protection Agency (FEPA) Act in 1988, which is also reported by Chokor (1993). Subsequent policies pursued by the Nigerian government were merely reactive control measures. The majority of the policies formulated were directed towards regulating pollution from the oil and gas industries, not putting into proper consideration other sources and their

health impacts (Osuji and Avwiri, 2005). In 2007, the FEPA Act was replaced by the National Assembly with the National Environmental Standards and Regulation Enforcement Agency (NESREA) Act. The responsibility for all environmental guidelines, laws, policies and standards in Nigeria is entrusted to NESREA. In 2019, NESREA began working to halve air pollution by ensuring environmental compliance and enforcement. Nigeria as a member of Climate and Clean Air Coalition (CCAC) since 2012, a partnership of over 160 governments and organisations is committed to reducing air pollutants.

Air being one of the most essential elements on earth has to be constantly managed so as to ensure its optimal quality. Around the world, numerous methods, policies, and interventions have been put into place to enhance air quality (Jafari et al., 2021). An efficient and successful instrument for controlling acceptable urban air quality is the urban air quality management plan (UAQMP) (Gulia *et al.*, 2015). Nigeria must enact specific environmental policy reforms and legislative changes based on a scientific understanding and analysis of the threats air pollution poses to public health in order to establish an air quality management framework. In order to accomplish this, Olowoporoku *et al.* (2011) identified four crucial components that must be taken into account. The first component is the creation of an empirical evidence basis for ambient air pollution by investigation and monitoring of Nigeria's air pollution issues' causes and effects. The creation of numerical air quality standards and limit values for specific contaminants that have the potential to endanger public health is the second. Third, strong laws and rules are required to ensure these requirements and to assign authority and responsibility for air quality to particular governmental organisations like NESREA and state government agencies. The establishment of a range of reasonable and affordable evaluation and management programmes, to be implemented at the local and national levels in order to meet the air quality objectives, is the last and most crucial step.

Monitoring of traffic volume and concentrations of carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxides (NO_x) and sulphur dioxide (SO₂) in areas of high traffic congestion provide support for road transportation emission control. The purpose of this study was to evaluate the amount of air pollution on three major roads in the city of Ibadan, which is known for its heavy traffic and regular urban route characteristics. This study will add to existing database and may assist the air regulatory body in policy improvement and evaluation. It may also provide a basis for mitigation measures.

2. METHODOLOGY

2.1 Study Area

Three locations within Ibadan city were purposely selected due to the existence of traffic in these areas and their characteristics of regular urban routes along commercial and residential areas in Ibadan. The three locations were Beere market road (L1), Mokola interchange (L2) and Oyo road near the University of Ibadan First Gate (L3). A reconnaissance of the locations was conducted to evaluate the feasibility of this study and get necessary information for proper planning. All three locations were characterised by high human and vehicular traffic due to the commercial and domestic activities in these areas. In the Beere Market road location (L1), road maintenance about 1km from the sampling area were ongoing during the period of the data collection. One notable activity around the sampling locations was the operation of numerous commercial centres, as well as domestic activities such as cooking using firewood fuels. Traffic volume/emission monitoring implemented consisted of automatic traffic count and air quality variables examination. The air quality variables examined are carbon monoxide (CO), carbon dioxide (CO₂), oxides of nitrogen (NO_x) and sulphur dioxide (SO₂). The monitoring was done from October to December 2019. The monitoring was done three periods daily, with each being for a duration of two hours. The data collected was carried out at 7:30am – 9:30am (Morning peak hours), 1:00pm – 3:00pm (Off-peak hours) and 5:00pm – 7:00pm (Evening peak hours) respectively. The emission data was compared with the World Health Organisation (WHO) standards.

2.2 Data collection

At each of the locations, traffic volume capturing the number of each component (cars, buses, motorcycles and tricycles) through automatic traffic count with the aid of a digital camera was carried out. The video recorded feeds were later reviewed to ascertain the traffic volume during the study. The presence of pollutant gases was measured by placing the equipment 2 m above ground level at the median of the highway. The monitoring of the air pollutants was done using a Smart Sensor AS8900 model multi-gas detector and an IOT-based device setup known as the Raspberry pi 3+ B model with gas sensor add-on. The former detected the carbon monoxide (CO) presence while the latter the carbon dioxide (CO₂), oxides of nitrogen (NO_x) and sulphur dioxide (SO₂) presence. The Raspberry pi device used Python language codes to record the presence of pollutants. Figure 2 shows the Raspberry pi setup used for the monitoring exercise. The pollutant concentration values were logged per seconds as Comma-Separated Values (CSV) files into the Raspberry pi device. The pollutant concentration values every 30 minutes of each of the three daily study periods was taken to calculate the average daily value of pollutants in the study locations. The equipment were calibrated and synchronised before the start of each monitoring period.

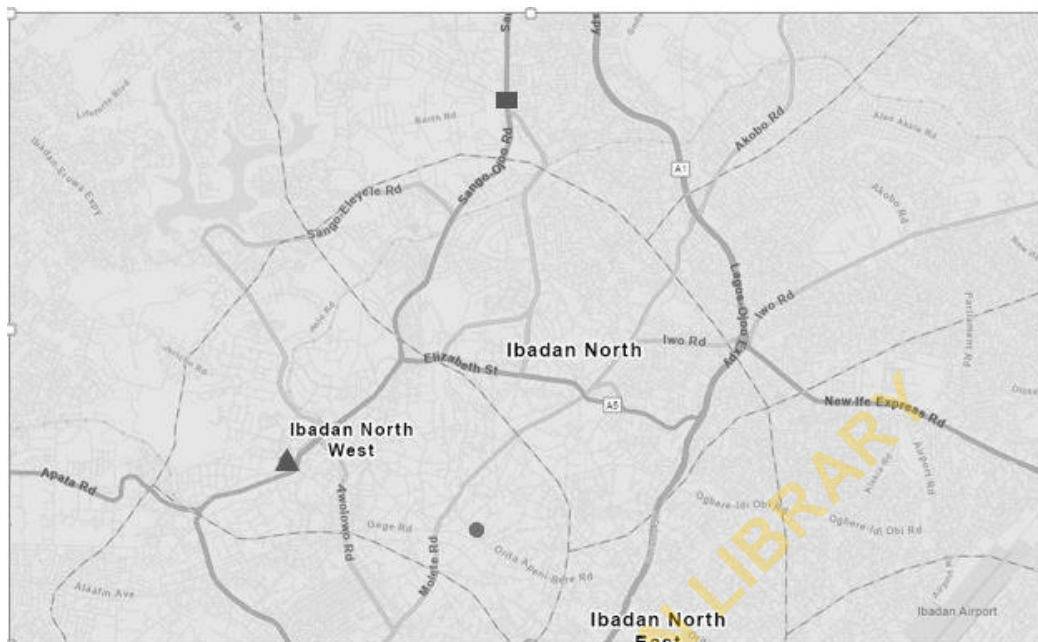


Figure 1: Map indicating study locations

Source: ArcGIS, 2019

- Legend:**
- Beere Market road, location (L1) 7°22'44"N 3°53'46"E
 - ▲ Mokola Roundabout, location (L2) 7°23'35"N 3°54'09"E
 - Oyo Road, near University of Ibadan Main Gate, location (L3) 7°31'43"N 3°55'01"E

3. RESULTS AND DISCUSSION

The monitoring exercise conducted indicated the level of air pollutant emission in the study area. The examined pollutants' concentration levels varied at each location. The average traffic volume in the locations for the study duration as shown in Table 1 were 966, 1057 and 916 for Beere market road, Mokola interchange and Oyo road near University of Ibadan First Gate locations respectively. Carbon monoxide pollutants resulting from vehicular emissions at the examined locations were in the range of 12 ppm to 48 ppm. The mean value of carbon monoxide (CO) gas emission was, 22.38 ppm, in the Beere Market road location (L1), a little below the 30 $\mu\text{g}/\text{m}^3$ (26.09 ppm) value set by the WHO. The number of vehicles recorded then was 4034. This value was obtained on a Monday afternoon.

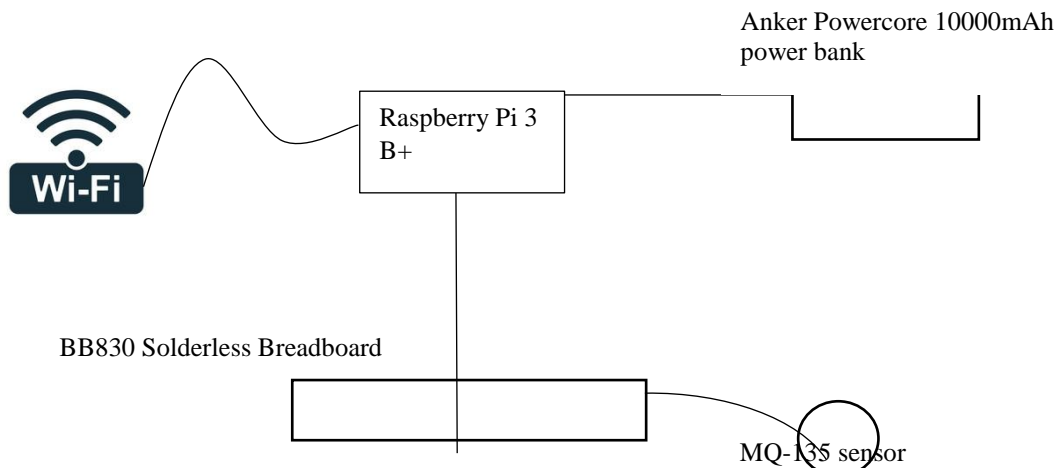


Figure 2: The Raspberry pi Air Quality Monitoring setup

Figure 3 shows the variation in the mean values of carbon monoxide emission in each monitored area, with the highest (24.20 ppm) recorded in the evening period of the Mokola interchange location (L2) and the lowest (19.78 ppm) in the afternoon period of this same location. A lower than WHO standard total carbon monoxide level of 21.81 ± 25.24 ppm is shown in Table 1. Higher average carbon monoxide concentration values were found in the morning and evening peak hours (with the maximum carbon monoxide emission value being 50.8 ppm) in an air pollution study conducted at main roads in Ibadan (Etim, 2016). Carbon monoxide values of (38.6 ± 22.2) ppm were recorded in a comparable investigation on gaseous emissions connected to vehicular traffic in Ibadan, Oyo state, Nigeria (Olamijulo and Godson, 2013). The data showed that there was little variation in carbon monoxide emissions between the three locations. The carbon dioxide emission may have been caused by the study area's high level of business activity, lack of greenery, and delayed burning of vehicle fuels.

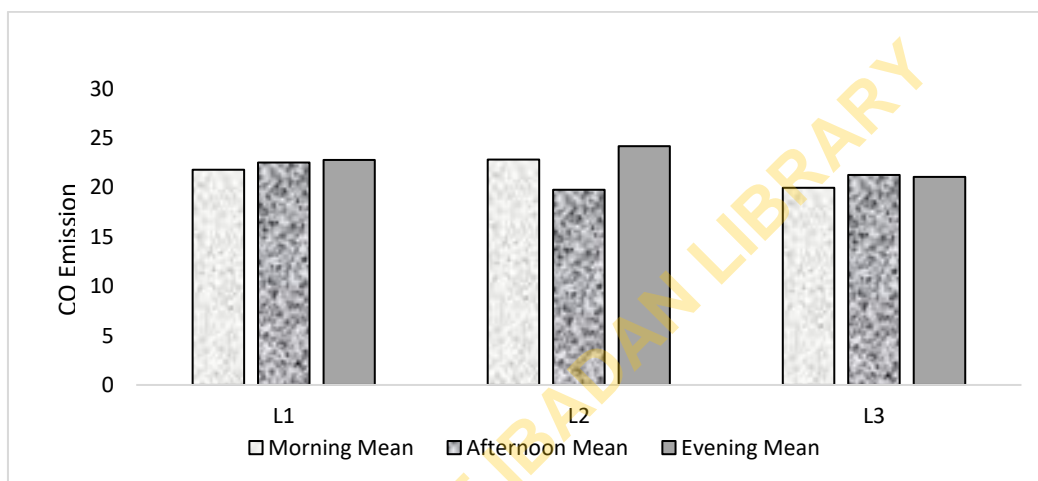


Figure 3: Mean value of carbon monoxide (CO) emission at each location

Table 1: Total Pollution Concentrations Comparing with WHO Guidelines and Mean Traffic Volume

Location Name/ GPS	Average Traffic Volume for study duration (numbers)	Overall Emission Concentration for study duration (ppm)				WHO Standard (ppm)			
		CO	CO ₂	NO _x	SO ₂	CO	CO ₂	NO _x	SO ₂
Beere Market Road (L1)	966/ 7.379281N 3.898888E	21.81 ± 25.24	411.92 ± 145.11	0.04 ± 0.02	0.004 ± 0.001	26.09	1000	0.10	0.008
Mokola Rounabout (L2)	1057/ 7.400822N 3.890232E								
Oyo road, near University of Ibadan Main Gate (L3)	916/ 7.441191N 3.906789E								

A high range of carbon dioxide (CO₂) emission was observed in the study locations. This range was from 108 ppm to as high as 624 ppm. However, the mean value of carbon dioxide emissions were generally lower than the WHO set standard of 1000 ppm. The maximum value of carbon dioxide of 506 ppm was observed in all three locations. The number of vehicles recorded alongside this high pollutant level were 4444 and 5064 respectively in the Beere Market road location. This value was observed in the afternoon period. Whereas, in the Mokola Interchange location, the number of vehicles recorded alongside the maximum mean value of carbon dioxide emission were 3641, 4264, 3956, and 4138 respectively. This value was observed in the morning and afternoon periods. In the Oyo road location near the University of Ibadan First Gate, the high emission value was recorded in two separate morning periods, with the number of vehicles being 4789 and 4347 respectively. Figure 4 shows the variation in the mean values of carbon dioxide emission in each monitored area, with the highest (469.50 ppm) recorded in the morning period of the Mokola interchange location (L2) and the lowest (335.92 ppm) in the afternoon period of the Oyo road location (L3). The overall carbon dioxide level, of 411.92 ± 145.11 ppm, is lower than the WHO set standard (see Table 1). From the analysis of the carbon dioxide emission, it is implied that there was a significant difference in the emitted gas among the locations under study. An air quality study conducted in Lagos, Nigeria recorded carbon dioxide emission levels of up to 397ppm in Lekki area of Lagos (Adeyanju and Manohar, 2017). In a study in an industrial area in Agbara, Ogun state, Nigeria reported carbon dioxide levels of (3.00 ± 2.05) ppm and the results were attributed to the meteorological conditions in the study location (Ojekunle *et al.*, 2018).

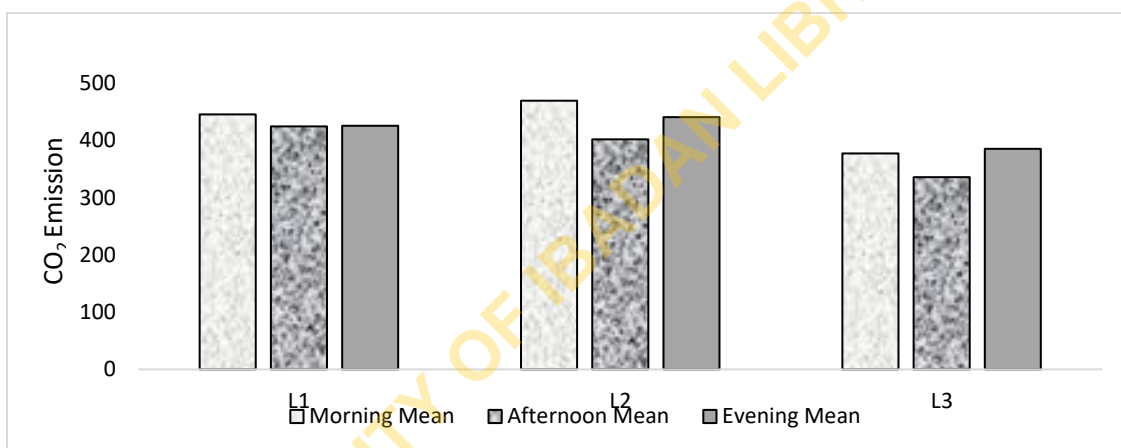


Figure 4: Mean value of carbon dioxide (CO₂) emission at each location

Average emission values of oxides of nitrogen (NO_x) ranged from 0.02 ppm to 0.08 ppm which is below the WHO set standard of 0.10 ppm. The maximum mean emission value for oxides of nitrogen of 0.04 ppm was recorded in the Oyo road location near the University of Ibadan First Gate. Figure 5 shows the variation in the mean values of oxides of nitrogen emission in each monitored area, with the highest (4.121×10^{-2} ppm) recorded in the evening period of the Mokola interchange location (L2) and the lowest (3.597×10^{-2} ppm) in the evening period of the Beere market road location (L1). This observation is similar to reports that found that nitrogen oxides values were higher in the afternoon than in the morning (Ipeaiyeda and Adegboyega, 2017) and it differs from a report that found low nitrogen oxides concentrations in the atmosphere were realised in the afternoon (Esen, 2005). The overall level of oxides of nitrogen emission recorded was 0.04 ± 0.02 ppm lower than the WHO set standard as shown in Table 1. This concentration level was relatively low and hence the possibility of the formation of ozone on ground level which could pose a threat to public health was low. Similarly, low nitrogen oxides concentration levels of 0.90 ± 0.32 ppm were reported in a study on air pollution in Agbara, Ogun state, Nigeria (Ojekunle *et al.*, 2018). From the analysis of the nitrogen oxides emission, it is implied that there was no significant difference in the emitted gas among the locations under study.

In the case of sulphur dioxide (SO₂), the highest mean emission value obtained was 0.006 ppm which is below the $20\mu\text{g}/\text{m}^3$ (0.008 ppm) standard set by the WHO. Figure 6 shows the variation in the mean values of sulphur dioxide emission in each monitored area, with the highest (4.69×10^{-3} ppm) recorded in the afternoon period of the Oyo road location (L3) and the lowest (3.58×10^{-3} ppm) in the morning period of this same location. In a similar study, conducted in Ibadan, Oyo State, Nigeria, on vehicular traffic-related gaseous emissions reported sulphur oxide levels of 1.00 ± 0.7 ppm (Olamijulo and Godson, 2013). The overall level of sulphur dioxide emission recorded was 0.004 ± 0.001 ppm lower than the WHO set standard as seen in Table 1. This low concentration level further reinforces the adherence to the Directive 2003/17/EC, by petrol and diesel manufacturers, which instructed modification in fuels, that ensure low sulphur content Etim (2016). From

the analysis of the sulphur dioxide emission, it is implied that there was no significant difference in the emitted sulphur dioxidegas among the locations under study.

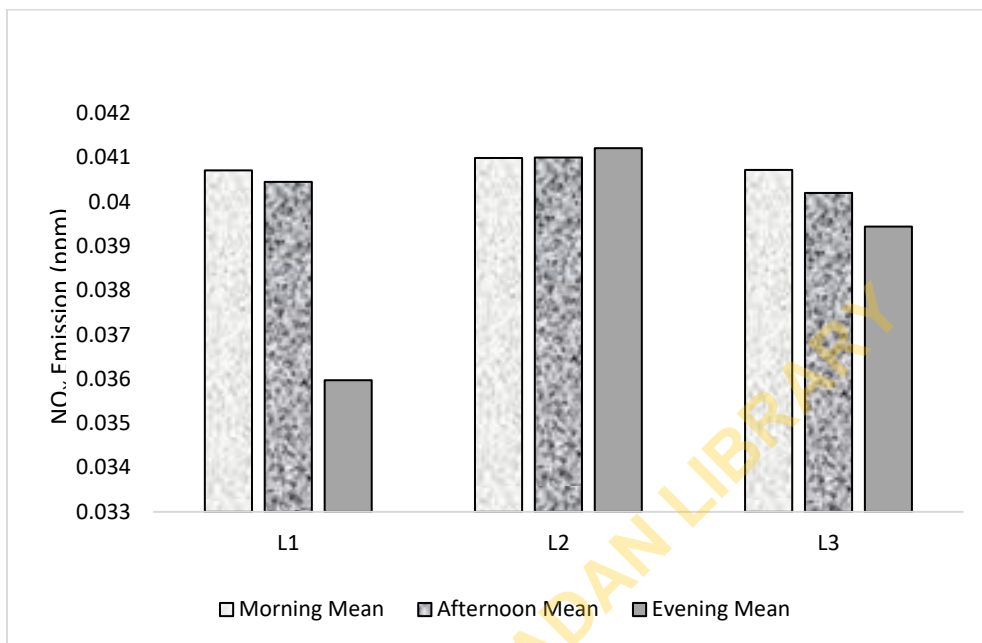


Figure 5: Mean value of oxides of nitrogen (NO_x) emission at each location

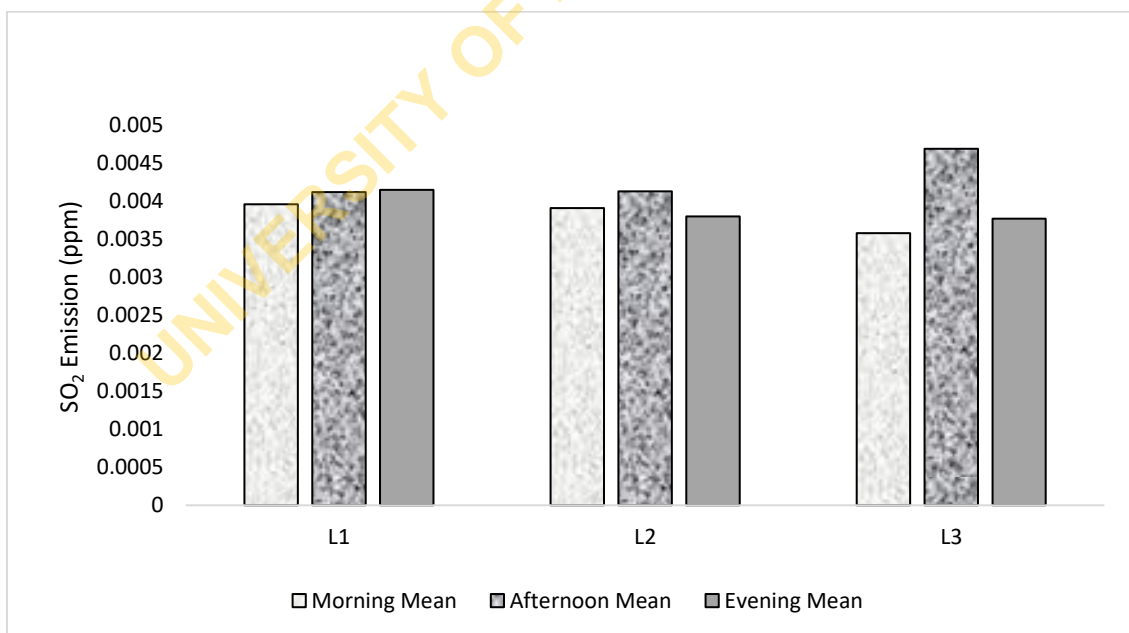


Figure 6: Mean value of sulphur dioxide (SO₂) emission at each location

4. CONCLUSION

According to this study, the three locations within the Ibadan metropolis have large emissions of carbon dioxide and carbon monoxide, which could be extremely harmful to the ecosystem overall. In order to prevent pollution, it is still necessary to make every effort to continuously monitor car emissions on highways, even though the high pollutant level present may have resulted from other factors than vehicle emissions. Vehicular traffic-related pollution in Ibadan may be a serious issue that requires investigation by the appropriate authorities. It is crucial to maintain the best possible air quality for the environment because it will affect human productivity and survival.

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