



ASSESSMENT OF AIR QUALITY OF SERVICE STATIONS IN A BUILT-UP AREA: A CASE STUDY OF LAGOS METROPOLIS

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ABSTRACT

Emissions emanating from commercial facilities in high dense area are subject of concern as more people are being hospitalised or suffering from long term exposure to poor air quality. Thus, there is the need to conduct assessment of air quality and other hazardous emissions in some commercial facilities. This paper presents the air quality index, formaldehyde and environmental emissions emanating from four service stations in Lagos metropolis. Four different filling stations were strategically selected from dense localities and monitored for about 8hrs per day for 30 days. The level of air qualities is assessed respectively for these locations. The data is time-averaged over the period of the data acquisition, and the results are presented. The air quality index for all the service stations were found to be below the recommended threshold by the World Health Organization (WHO) guidelines. The CO, CO₂ and HCHO emissions have similar pattern with respect to all locations monitored. Further analyses of emissions from different stations revealed that there is significant difference in service station B (SS B) from service station D (SS D) for CO₂ emissions at 95% confidence as P_{value} (0.04) is less than 0.05. A proportion of 51% of CO₂ can be accounted for by the emission variability in the service stations. However, there is no significant difference in the other emissions patterns at 95% confidence as P_{value} is greater than 0.05 (P_{value} >0.05) for AQI, CO, HCHO and TVOC emissions. In general, the emissions within the selected built-up areas were found not to sufficiently harm service station workers for short term exposure.

1.0 Introduction

In recent time, there are various reports of environmental concerns on public health emanating most especially from air pollution (Xiao et al., 2020, Parajuli et al., 2016, Sonibare et al., 2010, Heracleous and Michael, 2019, Azumaa et al., 2020, Tan et al., 2021). Air pollution is one of the leading menaces that are wrecking weighty atmospheric hazards on our ecosystem and human health. Human activities seem to be a major cause of releasing numerous life-threatening compounds into the environment. These emissions, in large quantities, are directly responsible for the lowering air quality of the respective environment. The potential associated hazards with the downstream sector of the petroleum value chain are often overlooked most especially in the cities where effect or the havoc of continuous emission could be swiftly felt.

Various researchers (Zhang et al., 2021, Xiao et al., 2020, Marc-Andre et al., 2007, Parajuli et al., 2016, Kassomenos et al., 2006, Sonibare et al., 2010, Heracleous and Michael, 2019, Azumaa et al., 2020, Tan et al., 2021) have conducted emission assessments of road traffic, industrial activities, commercial activities as well as secondary pollutants. Some dangerous pollutants (PM10, carbon monoxide (CO) and oxides of nitrogen) are identified by Muir et al., (2006).

Long term exposure to some of these pollutants can pose a risk of lung cancer, respiratory diseases, arteriosclerosis, as well as heart rate variability (Lelieveld et al., 2015, Brook et al., 2017, Zivin and Neidell, 2018, Darbre, 2018). CO is a poisonous gas emitted from incomplete combustion of hydrocarbons. Once it is taken up by the body system, CO diffuses into plasma and passes across the red blood cell membrane. It then enters the red blood cell cytoplasm where it is united with haemoglobin to form carboxyhemoglobin (COHb). The affinity of the red blood cells for CO is 210 – 300 times greater than for oxygen (Fang et al., 2006). This will prevent tissue respiration and the organism may eventually die of oxygen starvation.

Despite the growing trends of studies on atmospheric pollution, the long term health effects of air pollution remain largely unknown due to the fact that the blanket control of the harm is insufficient, and the combined effect of several contaminants is frequently eclipsed by the severe contributions of primary contaminants (Lelieveld et al., 2015; Kelly and Fussell, 2011). The global burden of death reiterated that, air pollution killed 4.9 million people worldwide in 2017 (Stanaway et al., 2018).

Air pollution constitutes a major public health issue in both developed and developing countries. According to (Nguyen and Kim, 2006), about 2.7 million people die annually as a result of air pollution all over the world. As a direct consequence of swiftly growing industrialization across the entire planet, the quality of air around us keeps dropping. This is undoubtedly undesirable, as it has both short and long terms effects on the life expectancy most especially in developing and under developed countries.

The air quality index, or sometimes called air pollution index, is a unified index that summarizes the concentrations of various pollutants in a single index. The pollutants are then categorized to determine the efficiency of dissemination discharge and utilization in different regions (Plaia and Ruggieri, 2010). This helps in the reliable comparison of air quality patterns over time and space, as well as the prediction and possible caveat of air pollution (Mirabelli et al., 2020). A number of AQIs based on various sub-indicators and calculation methodologies have been developed by researchers depending on local air quality scenarios as well as national standards to account for changes in air quality and management requirements among countries (Kanchan et al., 2015). However, it is really difficult to use existing AQIs for local or regional comparison due to their weak comparability and cross-applicability. Therefore, most regions and territories need to generate their own data and determine the possible effect on life. It should be noted that most AQIs used by some regions and countries are currently based on a single major pollutant rather than the overall air quality (Perlmutter et al., 2017) which may significantly underestimate the impact of numerous contaminants. Hence, the need to develop data for various regions within Nigeria on the safety compliance with standard methods or practices is imperative.

Very recently, the commercial activities of service stations in Lagos metropolis are becoming a threat to the environment and the people staying within that environment as some regulations or the available regulations are perceived to be violated by the various stakeholders that are involved for the commercial dispensing of hydrocarbons. In some cases, there is serious oil spillage that ultimately affect the immediate environment. The safety of the fuel dispensing environment is also a subject of concern. In the past, filling stations are usually located on the outskirts of the cities because of the perceived danger of fuel to life, however, filling stations are becoming features of residential areas now. Some of the filling stations have also extended their operations to include sales of cooking gas, lube bay, shopping malls, gas cylinders, and vehicle servicing. Clusters of service stations in residential areas are source of concerns for residents in some areas. The close proximity to residential structures is one of the main issues causing fatal destructions which are usually experienced in accident situation.

Furthermore, there are growing numbers of illegal filling stations in Lagos and these numbers could increase significantly in the coming years if regulations and enforcement are not put in place. The activities of legal and the illegal filling stations could negatively affect the air quality around residential areas. These issues have necessitated this research as serious concern is growing among Lagos residents on the possible implication on health and safety. Some highly built up areas where the environmental menace seems dominant are selected for this research to ascertain the effect of the commercial activities of service stations in the area. Commercially dense areas were chosen for this study because of the huge potential effect on large number of people and the subsequent over stretching of the health facilities. This study presents the air quality assessment around four service stations in Lagos metropolis. Each service station was randomly selected from east, north, west, and south of Lagos metropolis.

2. Materials and Methods

2.1 Study Area

Lagos State (with Latitude 6.5227°N , and Longitude 3.6218°E) is located in the south western part of Nigeria and is regarded as one of the top ten fastest growing urban areas of the world (Diop et al., 2014, UN-HABITAT, 2006). The approximate size of Lagos is $1,171.3\text{km}^2$ with water occupying about 172km^2 as shown in Figure 1. It is mainly bothered in the north by Ogun State and in the south by Atlantic Ocean. It is the economic and financial hub of Africa with huge urban agglomeration of residents (City-Population, 2015). It is the largest metropolitan city in Africa with numerous intrinsic challenges associated with its unfolding evolution. City of Lagos is also known for many commercial activities like petroleum related businesses, industrialization among others. Some of the key metros of the study area are shown in Figure 1 with the various service stations locations where data were logged.

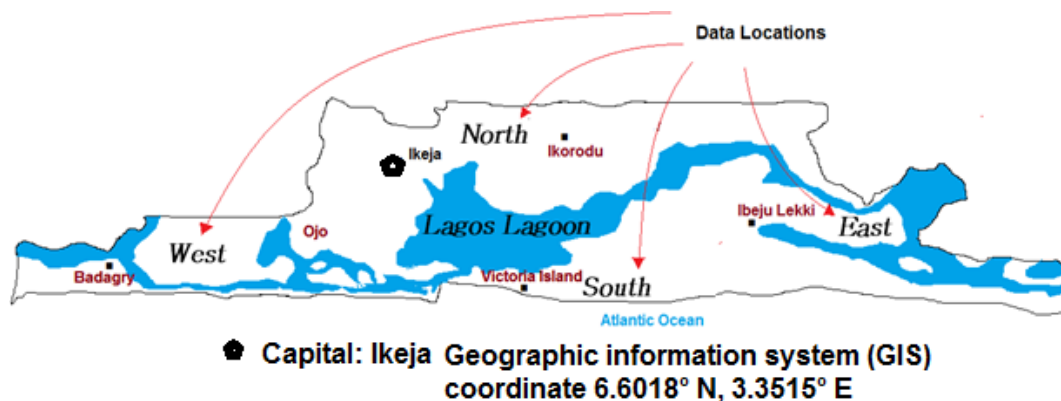


Figure 1: Map of Lagos metropolis (6.5227°N , 3.6218°E)

2.2 Data acquisition process

Four filling stations were selected in strategic positions in Lagos metropolis due large number of people engaging in hydrocarbon related commercial activities on a daily basis. Common emissions were chosen for this research. CO , CO_2 and formaldehyde HCHO were monitored for four months with the aid of air analyzer (Model number, B09288J77J; PalliPartners, China). All these emissions CO , CO_2 and formaldehyde HCHO were selected based on prevalence, relevance to air quality assessment and immediate health implication. For instance, CO is a very common atmospheric pollutant whereas CO_2 is a greenhouse gas responsible for global warming; climate change and the duo are primarily associated with hydrocarbons. Carbon monoxide is known to be toxic and can cause cardiovascular problems even at low concentration. It is therefore important in assessing CO level to determine the air quality. However, CO_2 level is crucial for the understanding of impact of human activities on the immediate environment. Again, choosing formaldehyde (HCHO) along with CO and CO_2 as it is also associated with structures, vehicular emissions. It can also cause respiratory irritation, and has the propensity for carcinogenicity.

Meteorological parameters (Temperature, Precipitation, humidity and wind speed) were also obtained for the four locations. The four filling stations were selected based on the main four regional areas of Lagos (Figure 1). The selected filling stations were chosen on the basis of high commercial activities and perceived environmental threat. The selected service stations are designated as -1, -2, -3 and -4 respectively. Service station-1, -2, -3 and -4 are located on the western (6.4183°N, 2.8301°E), eastern (6.4569°N, 3.8859°E), southern (6.4281°N, 3.4219°E) and northern (6.6194°N, 3.5105°E) parts of Lagos State respectively. All the four service stations have an average fuel dispense stands of about 6 numbers. Four locations are measured away from each of the dispenser packs at about 3m in all the four cardinal directions. The locations are also designated south, east, west and north. These data were monitored over three periods of the day during the dry season of the year: (a) two hours in the morning; (b) two hours in the afternoon; and (c) two hours in the evening.

The emissions were measured monitored at the nose level of an average height of attendants at the various selected stations to determine the likelihood of the level of risk that the attendants are exposed to during the working hours in the various service stations.

Baseline data were obtained from all the filling stations before the scheduled daily monitoring. The baseline data are taken outside the territory of each of the filling stations. These locations are chosen strategically to calibrate the gas analyzer and are free from hydrocarbon emissions. The various data obtained were time-averaged to obtain single data for each location at respective filling station. The data were further processed according to Navidi (2021) by employing analysis of means or variance (ANOVA) and compared with the available standards locally and internationally. Equation 1 (Shihab, 2023) are used to obtain the air quality index data according to geometric mean method with AQI range from 0 -125+.

The uncertainty in the experimental data for all the emissions is less than 5%. This was obtained using the magnitude of the bias and the precision uncertainties in the measurements.

$$AQI = \frac{(I_h - I_l)(C_c - C_l)}{(C_h - C_l)} + I_l \quad (1)$$

Where I_h is the index break point corresponding to C_h ; I_l is the index break point corresponding C_l ; C_c is the pollutant concentration; C_l is the concentration breakpoint that is $\leq C_c$, and C_h is the concentration breakpoint that is $\geq C_c$.

3. Results and Discussion

3.1 Meteorological Air Quality

Averaged meteorological parameters like the temperature, wind speed, humidity and precipitation are monitored and presented in Table 1. It also provides the essential background meteorological information which has direct implications on activities relating to discharge of hydrocarbons into the neighbourhood. The table basically indicates the usual or expected values for a normal environment that is safe for anyone to stay while performing his or her daily routine task. Meteorological Air quality index gives indication or insight to how dangerous the air around is, as it tracks the smog level, exhaust, dust as well as other pollutants.

Table 1: Mean meteorological values

Meteorological parameter	Measurement value
Temperature	30°C
Precipitation	0%
Wind speed	13km/h
Humidity	84%
Air density	1.03

3.2 Air Quality Index

The air quality is obtained in-situ from the emission analyzer equipment by using Equation 1. The data for the Air quality index is presented in Figure 2. Averaged data (AV) and the error gap in the data for all the filling stations are also presented in Figure 2. In Figure 2, the abscissa denotes the various locations ('N' for North, 'W' for West, 'E' for East, 'S' for South) along the horizontal direction while the ordinate represents the measured AQI. On the legend, 'SS' implies service (filling) station and letters 'A to D' just in front of SS represents the various stations monitored. For all the plots, break point for the air quality are clearly not exceeded as all of the data fall below it and are within the desirable region for the air quality of the filling stations monitored. This shows that all the filling stations are World Health Organization compliant. The guidelines of WHO are intended to serve as a reference for various governments in setting air quality targets and implementing measures to reduce exposure to malicious air pollutants.

Air quality index value above the break point line is considered 'moderate' in terms of its effect on the health of individual over a long period of time. Magnification (Figure 2) of the line plots of the various service stations shows that there are clear variations in the relationship between all the AQI data presented for all the four locations. There is a gradual increase in the AQI as shown in the averaged data (AV) from all the four service stations. This could be attributed to the direction of wind which is apparently from north-west to south-east. The difference in the AQI can be seen with station-c having the lowest values all through the four locations.

Further analyses were carried out to determine whether there is significant difference in the AQI for all the four stations. The results revealed that P_{value} is greater than 0.05 at 95% confidence. This shows that there is no significant difference in the emissions as a result of different locations of the filling station. This implies that analyzing data from one of the filling stations monitored in Lagos metropolis suffices for the air quality in any of the four locations.

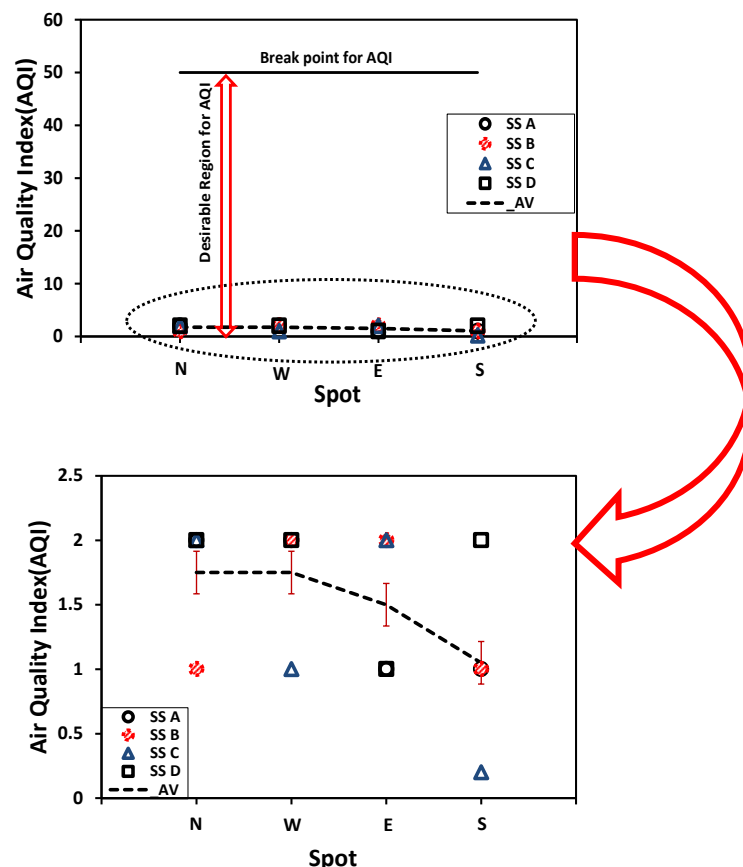


Figure 2: Air quality index in four different locations

3.3 CO and CO₂ Emissions

The emissions of CO and CO₂ were measured in parts per million (ppm). The patterns of the emissions seem similar to each other. Figures 3 and 4, show that there is increase in CO and CO₂ emissions from the north-west to the south-east for all the service stations monitored. This could be attributed to the direction of the wind. The wind direction seems to play a role on the concentration of the CO and CO₂ emissions in all the service stations. Further analysis on whether there is disparity in the respective emissions (CO and CO₂) as a result of difference in locations reveals that at 90% confidence, there is no significant difference as a result of change in location within all the filling stations respectively. That means monitoring one of the four filling stations in Lagos metropolis is sufficient to obtain reasonable information. However, Figure 4 revealed that at 95% confidence, there is significant difference in CO₂ emissions in service station B when compared with that of service station D as $P_{value} (0.04) < 0.05$. The emission variability of over 50% of CO₂ can be accounted for by the two reference service stations -B and -D. The study showed that the threshold for CO emissions is not exceeded. This suggests that long term exposure to CO/CO₂ due to the commercial activities involving hydrocarbons may not necessarily affect or harm the attendants.

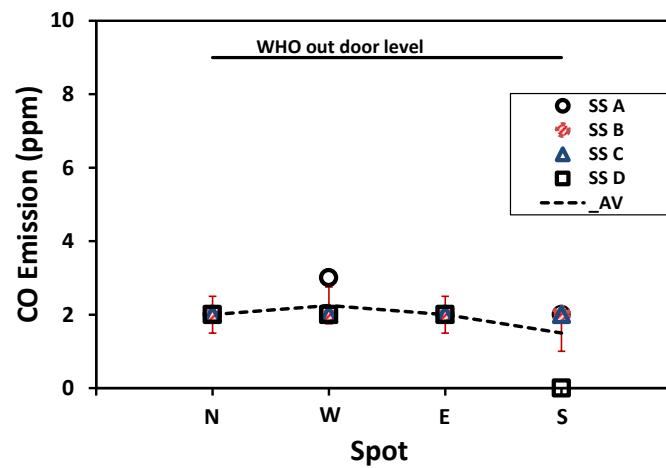


Figure 3: Carbon monoxide emissions (ppm) from four different service stations

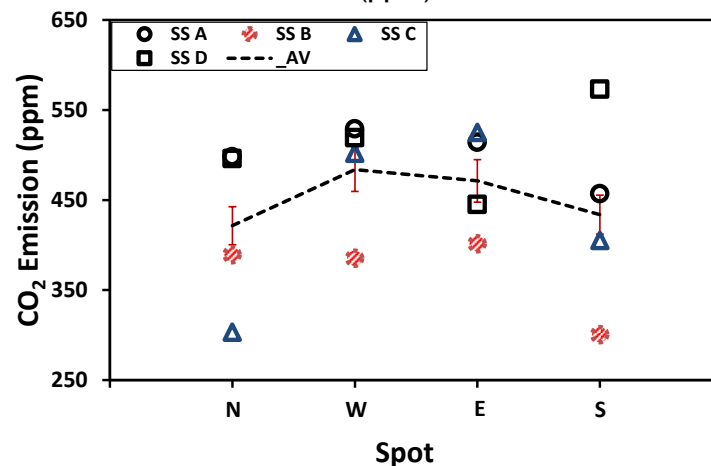


Figure 4: Carbon dioxide emissions (ppm) from four different service stations

3.4 Emission of Formaldehyde

The emission pattern of formaldehyde is presented in Figure 5 for all the stations monitored. It was observed that, the northern locations of all the service stations monitored showed value lower than that of the other three locations. This might also be due to the direction of the wind. However, since P_{value} exceeds 0.05, there is no discernable difference in the emission pattern at 95% confidence regarding the location change for any of the four filling stations.

3.5 Comparative Evaluation of all the Emissions

Table 2 shows the ground average for all the emissions within the four service station locations. The values for CO, AQI, and HCOC conform to standard. The average of all the emissions per location is presented in Figure 6. The results show that the emission patterns are all similar throughout the period of the investigations. For CO emission, comparison of individual filling stations to that of the ground averaged emission revealed that all the emissions are close in magnitude that of the ground averaged value with only service station B slightly having lesser ground averaged emission value. However, service station A has marginal increase in the CO, HCHO and TVOC compared to other locations. This could be attributed to the convectational current of the wind.

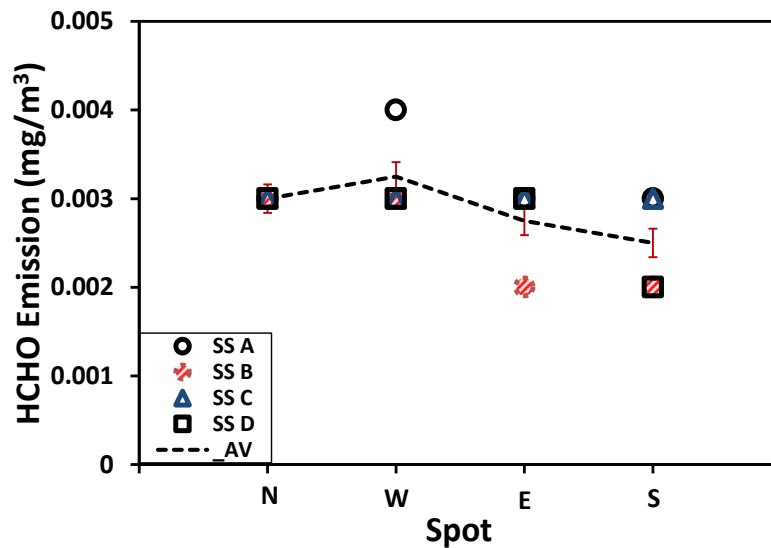
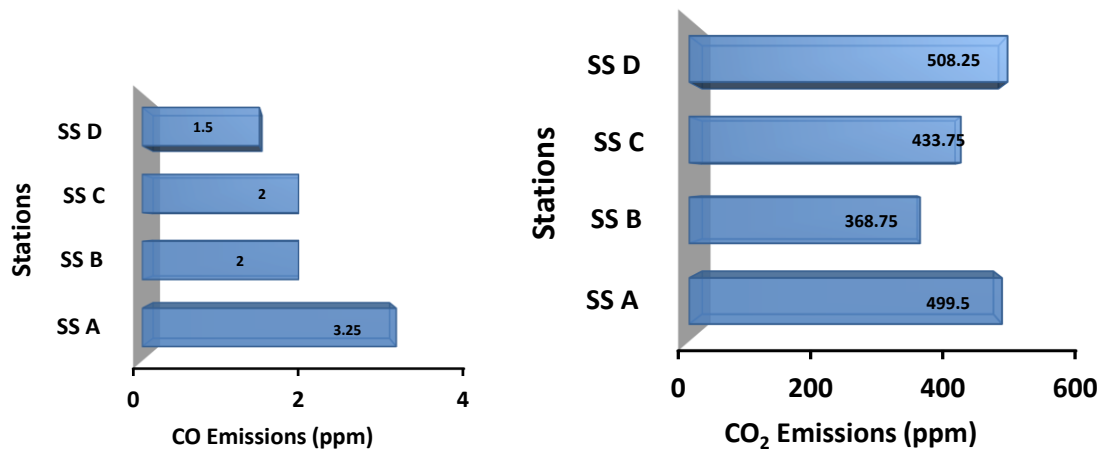


Figure 5: Formaldehyde (HCHO) emissions (mg/m³)

Table 2: Averaged value of the emissions at all the four locations

Emissions	Ground averaged value
TVOC (mg/m ³)	0.006
AQI	1.512
CO (ppm)	2.188
CO ₂ (ppm)	452.6
HCHO (mg/m ³)	0.003



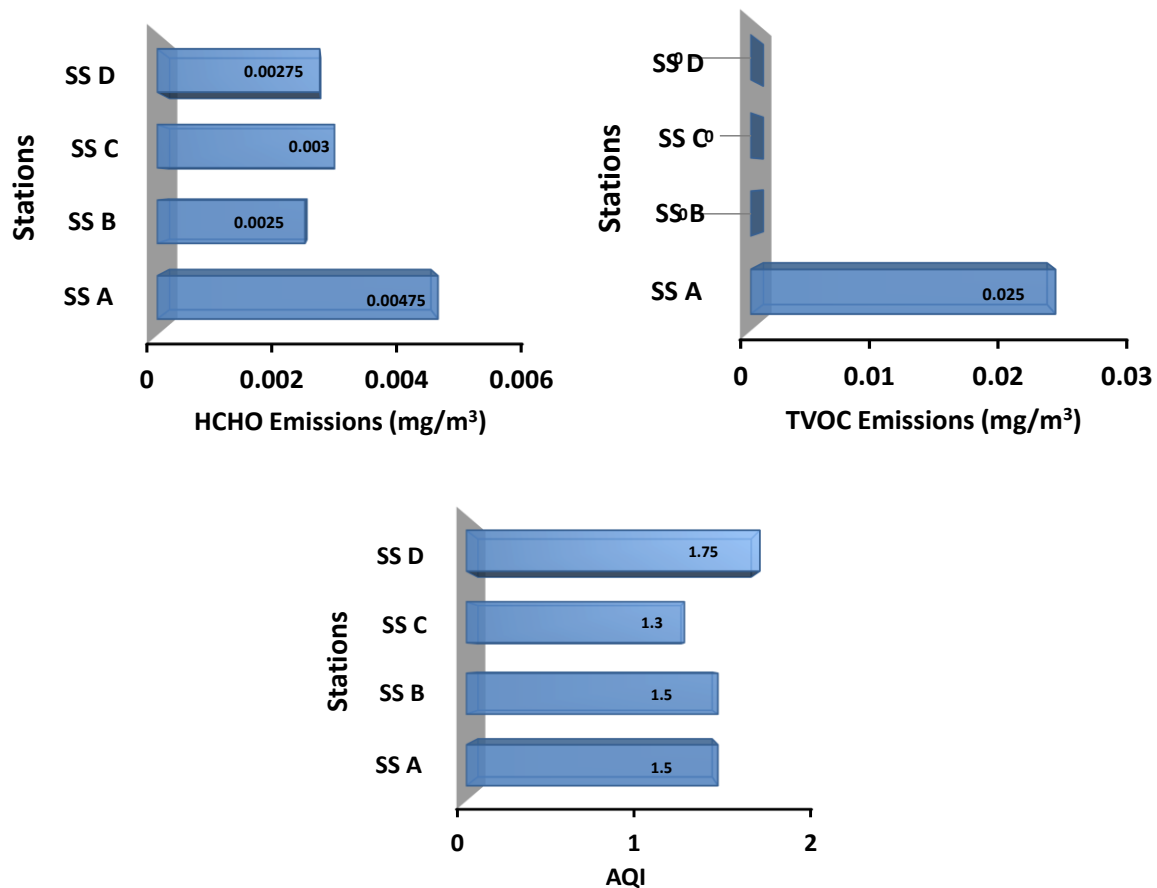


Figure 6: Comparison of means for all the emissions and air quality index (a) CO, (b) CO₂, (d) HCHO and (d) TVOC (e) AQI

4. Conclusions

It is very important to acquired and analyse the prevailing air quality characteristics at various locations within Lagos metropolis so that it can form and improve government legislation on the location and localization of industries within Lagos sphere.

Every company dealing with hydrocarbons cited within the residential area is expected to follow a certain standard because of the health issues or the possible damage or long-term havoc as a result of prolonged exposure to such gaseous chemicals. The data here will certainly help the various stakeholders including the investors and the government to properly regulate the activities of these companies.

The most prominent lethal emissions are assessed and monitored in service stations in Lagos State, in this research at four different locations. The data obtained are subjected to analysis of variance. The following conclusions are hereby arrived at:

- The AQI conform to standard in all the four filling stations. About 20% in the AQI variability in the service stations can be accounted for. CO and CO₂ need to be watched and possibly attenuated as they are more lethal compared to others.
- At 90% confidence, there is no difference in all the emissions with respect to all the four locations. Therefore, difference in locations is not significantly affecting the emission patterns. It suffices that emissions data for a location away from the nozzle points are sufficient for all the other data from the other similar equi-distance locations from the reference nozzle point.
- There is significant difference in SS B from SS D for CO₂ emissions at 95% confidence as P_{value} (0.04) is less than 0.05. About 51% of CO₂ can be accounted for by the emission variability in the service stations. However, there is no significant difference with respect to other service stations combination ($P_{value} > 0.05$).

It is recommended that service stations in highly populated cities like Lagos are expected to do routine environmental assessment, at least annually, to determine and control the unforeseeable environmental consequences that may emanate from increase in the volume of their commercial activities. Governments are encouraged to legislate on this and make it a by-law in the interest of conservation of our biodiversity.

- The data thus presented will also complement the available data in the literature.

Reference

Azumaa, K., Jinnob, H., Tanaka-Kagawa, T. and Sakai, S. 2020. Risk assessment concepts and approaches for indoor air chemicals in Japan. *International Journal of Hygiene and Environmental Health*, 225: 113470.

Brook, RD., Newby, DE. and Rajagopalan, S. 2017. The global threat of outdoor ambient air pollution to cardiovascular health: time for intervention. *JAMA Cardiology*, 2: 353–4.

City-Population. 2015. Metro Lagos (Nigeria): Local Government Area, Retrieved 16th Oct., 2021.

Darbre, PD. 2018. Overview of air pollution and endocrine disorders. *International Journal of General Medicine*, 11: 191–207.

Diop, S., Barousseau, JP. and Descamps, C. 2014. The Land and Ocean Interaction in the Coastal Zone of West and Central Africa Estuaries of the World. Dallas, Springer, p. 66.

Fang, GC., Wu, YS., Chen, JC., Rau, JY., Huang, SH. and Lin, CK. 2006. Concentrations of ambient air particulates (TSP, PM_{2.5} and PM_{2.5–10}) and ionic species at offshore areas near Taiwan Strait. *Journal of Hazardous Materials*, 132: 269-276.

Heracleous, C. and Michael, A. 2019. Experimental assessment of the impact of natural ventilation on indoor air quality. *Journal of Building Engineering*, 26: 100917.

Kanchan, K., Gorai, AK. and Goyal, P. 2015. A review on air quality indexing system. *Asian Journal of Atmospheric Environment*, 9: 101–113.

Kassomenos, P., Karakitsios, S. and Papaloukas, C. 2006. Estimation of daily traffic emissions in a South-European urban agglomeration during a workday. Evaluation of several “what if” scenarios. *Science of the Total Environment*, 370: 480-490.

Kelly, FJ. and Fussell, JC. 2011. Air pollution and airway disease. *Clinical & Experimental Allergy*, 41(8): 1059-1071.

Lelieveld, J., Evans JS., Fnais, M., Giannadaki, D. and Pozzer, A. 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*, 525: 367–371.

Marc-Andre, R., Chimonasa, MR., Bradford, D. and Gessne, BD. 2007. Airborne particulate matter from primarily geologic, non-industrial sources at levels below National Ambient Air Quality Standards is associated with patient visits for asthma and quick-relief medication prescriptions among children less than 20 years old enrolled in Medicaid in Anchorage. *Alaska Environmental Research*, 103: 397-404.

Mirabelli, MC., Ebelt, S. and Damon, SA. 2020. Air Quality Index and air quality awareness among adults in the United States. *Environmental Research*, 183: 109185.

Muir, D., Longhurst, JWS. and Tubb, A. 2006. Characterization and quantification of the sources of PM10 during air pollution episodes in the UK. *Science of the Total Environment*, 358: 188-205.

Navidi, W. 2021. *Statistics for Engineers and Scientists*. McGraw-Hill Education, New Delhi.

Nguyen, HT. and Kim, KH. 2006. Comparison of spatiotemporal distribution patterns of NO₂ between four different types of air quality monitoring stations. *Chemosphere*, 65: 201-212.

Parajuli, I., Lee, H. and Shrestha, KR. 2016. Indoor Air Quality and ventilation assessment of rural mountainous households of Nepal. *International Journal of Sustainable Built Environment*, 5: 301–311.

Perlmutter, L., Stieb, D. and Cromar, K. 2017. Accuracy of quantification of risk using a single-pollutant Air Quality Index. *Journal of Exposure Science and Environmental Epidemiology*, 27: 24–32.

Plaia, A. and Ruggieri, M. 2010. Air quality indices: a review. *Review of Environmental Science and Biotechnology*, 10: 165–179.

Shihab, A. 2023. Assessment of air quality through multiple air quality index models - a comparative study. *Journal of Ecological Engineering*, 24(4): 110-116.

Sonibare, JA., Adebisi, FM., Obanijesu, EO. and Okelana, OA. 2010. Air quality index pattern around petroleum. *Management of Environmental Quality*, 21: 379-392.

Stanaway, JD., Afshin, A., Gakidou, E., Lim, SS., Abate, D., Abate, KH., Abbafati, C., Abbasi, N., Abbastabar, H. and Abd-Allah, F. 2018. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study. *Lancet*, 392: 1923–1994.

Tan, X., Han, L., Zhang, X., Zhou, W., Li, W. and Qian, Y. 2021. A review of current air quality indexes and improvements under the multi-contaminant air pollution exposure. *Journal of Environmental Management*, 279: 111681.

UN-HABITAT. 2006. *African Cities Driving the NEPAD Initiative*, p. 202.

Xiao, C., Chang, M., Guo, P., Gu, M. and Li, Y. 2020. Analysis of air quality characteristics of Beijing-Tianjin-Hebei and its surrounding air pollution transport channel cities in China. *Journal of Environmental Sciences*, 87: 213 – 227.

Zhang, J., Li, H., Lei, M. and Zhang, L. 2021. The impact of the COVID-19 outbreak on the air quality in China_ Evidence from a quasi-natural experiment. *Journal of Cleaner Production*, 296: 126475.

Zivin, JG. and Neidell, M. 2018. Air pollution's hidden impacts. *Science*, 359: 39–40.