



Spatial & Temporal Variation of Ambient Air Pollution in Kaduna Metropolis

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ABSTRACT

Urban air quality is a major environmental concern around the world, and its significance is increasing as the world becomes more urbanised. Many cities in Nigeria have rapidly growing populations, with increased motorisation and energy use, leading to significant air pollution. Particulate matter (PM) is an air pollutant which has been identified as a serious risk to human health. Air pollution varies both spatially and temporally. The aim of this study is to assess the spatial and temporal variation of particulate matter (PM) pollution in Kaduna Metropolis, and to map the hotspots of PM pollution. Air quality detector (Model: DZ8600) was used to collect the particulate matter (PM10 and PM2.5) data. Space time sampling technique was used in collecting the data and sampling was done in both wet and dry season. The spatial variation of the pollutants was described using Inverse Distance Weighing tool of Geographical Information Systems (GIS) and satellite imagery of the study area was obtained from Kaduna Geographical Information System. The findings indicate high levels of PM10 and PM2.5 along many of the sample points which conform to high traffic density areas in Kaduna metropolis, and most results exceeded the EPA and NESREA standards. The findings also show a significant difference in the concentration of the pollutants between the wet and dry seasons, as there is an increase in the area covered by these pollutants from during the dry season. The study recommends the formulation of an urban air quality management plan, and the use of nature-based solutions to improve air quality.

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INTRODUCTION

Urban air quality is a major environmental concern around the world, and its significance is increasing as the world becomes more urbanized. One of the key reasons for rising air pollution levels in low and middle income countries is rapid urbanization combined with industrial growth (Katoto et al 2019). By 2050, Africa is expected to house nearly a quarter (1.3 billion) of the world's urban population (Cobbinah et al., 2015).

In recent years many African countries have experienced significant economic growth leading to increased urbanization, motorization and energy use (Jackson, 2015; Othman, 2016). Air pollution generated by motor vehicular exhaust has become a major cause of public concern worldwide and in Africa. In urban areas, the rapid growth of motor vehicle traffic and the related gaseous pollutants has resulted in a substantial

increase in the prevalence of respiratory disorders (Zhang & Batterman, 2013). The net effect of this increase in population and cars is the drastic increase in environmental pollution including air pollution (Jackson, 2015). Urban air pollution has been associated with increased morbidity and mortality (WHO, 2015) and pollutant levels far exceed desired levels or standards in many cities. In spite of the successful efforts to reduce air pollution in industrially developed countries, mortality and morbidity attributable to air pollution have not decreased on a global level. In the year 2016, ambient air pollution was responsible for 4.2 million deaths (Global Health Observatory Data, 2018). According to the United Nations, 600 million people in urban areas globally are exposed to harmful amounts of traffic-related air pollution (Cacciola et al., 2018).

Aged engines, poor fuel grades, absence of adequate maintenance, excessive



vehicle use, and lubricant misuse (particularly in motorcycles) all combine to prevent optimal fuel combustion. As a result, carbon monoxide (CO), Hydrocarbons (HCs), Nitrogen oxide (NO₂), Sulphur dioxide (SO₂) and Particulate matter (PM) are emitted from the vehicles (Katoto et al., 2019; Sun et al., 2022).

Air pollution is associated with a broad spectrum of acute and chronic illness, such as lung cancer, chronic obstructive pulmonary disease (COPD) and cardiovascular diseases (Orach et al., 2021). In 2013, the World Health Organisation (WHO) classified particulate matter (PM) as carcinogenic to humans, responsible for the deaths of 3.7 million people worldwide each year. PM₁₀ (particles ≤ 10 microns) is a criteria pollutant and is a serious health risk because PM₁₀ particles can penetrate the lungs. PM_{2.5} (particles ≤ 2.5 microns) is also a criteria pollutant which has even greater health impact due to risk of penetration deeper into the respiratory system. Studies have linked particulate pollution to lung and heart disease, strokes, and cancer.

LITERATURE REVIEW

Data from Africa suggests vehicular traffic, industries, wildfires, and biomass burning as significant sources of PM, CO, NO₂, SO₂, and VOCs. Dust from the Sahara Desert is a major source of PM pollution in the region especially during the Harmattan season. According to a recent review () only 10 and 13% of the reported annual and 24-hour mean ambient PM concentrations are lower than the relevant WHO AQG for PM_{2.5}, and for PM₁₀, 12% (Agbo et al., 2021). This suggests that most African towns have unhealthy levels of PM in air. Several recent studies have revealed that spatial and temporal factors affect the concentration of air pollutants. Gulia et al. (2020) study showed how satellite-based remote sensing monitoring calibrated with ground level measurements can be used to monitor regional air quality.

Sertel et al. (2018) studied spatial prediction of transport related urban air quality in Turkey using Kriging method. The meteorological and topographical conditions the area affects the dispersion of atmospheric pollutants and is an important factor in urban air pollution the atmospheric pollutants dispersion (Macedo et al., 2020). The result shows a significant increase of the pollutants in winter and a significant decrease of these pollutants in summer. Taiwo et al. (2015) reviewed PM pollution studies in all the

geopolitical zones in Nigeria. The result showed that most of the reported PM mass concentrations in Nigeria were higher than the annual World Health Organization standards. Dimari et al (2018) studied pollution synergy from the concurrence of the harmattan, fugitive dust and combustion emissions in Maiduguri metropolis and found that harmattan dust contributes to the spatial distribution of the particulate matters. The aim of this study is to assess the spatial and temporal variation of particulate matter (PM) pollution in Kaduna Metropolis.

METHODOLOGY

Study Area

Kaduna metropolis is located between latitude 10°38'58"N and 10°25'36" North of the equator to longitude 7°22'14" E and 7°32'00" East of the Greenwich Meridian. The study area stretches across Kaduna North Local Government Area and Kaduna South as well as part of Igabi and Chikun Local Government Areas. Kaduna metropolis serves as the capital and seat of Kaduna State Government (Yusuf, 2015).

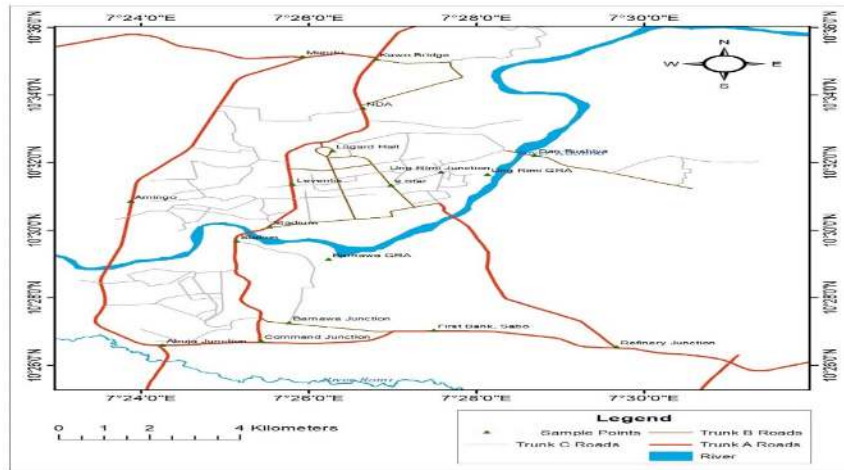


Figure 1: Study Area

Sampling Design

Purposive sampling method used for choosing the sampling locations. These sampling sites are areas of high traffic density in the metropolis. They include; Mando R/about, Amingo Junction, Abuja Junction, Command Junction, Refinery Junction, Kawo Bridge, Leventis R/about, Station R/about, Lugard Hall, Nine (9) Star Junction, Barnawa Junction, First Bank Sabo, Unguwan Rimi Bus stop, Stadium R/about and Hayin Dan Bushiya road.

MATERIALS

GPS device (Gamin 76csx + or – 3 meter accuracy) was used to collect the precise sample locations and air monitoring device (DI.ZENE Air quality detector Model: DZ8600) was used to collect the particulate matter (PM10 and PM2.5) data. Satellite imagery of the study area was obtained from Kaduna Geographical Information System.

Data Collection

Sampling was done for wet season from July, 2019 to September, 2019 (three days from each month) and December, 2019 to February, 2020 for dry season (three days from each month). Space time sampling technique was used in collecting the data. All sampling locations were sampled at different times of the day (morning, afternoon and evening). Morning readings were taken between 7am - 9:30am, afternoon readings between 12:30pm - 3pm and evening readings were taken between 5pm - 7:30pm. Sampling involved open air sampling on the pavements in closest proximity to the roads. Measurements were taken after steadying the equipment before readings were taken in order to provide real time reading of particulate matters (PM10 and PM2.5).

RESULTS & DISCUSSION

Pollutant Concentrations

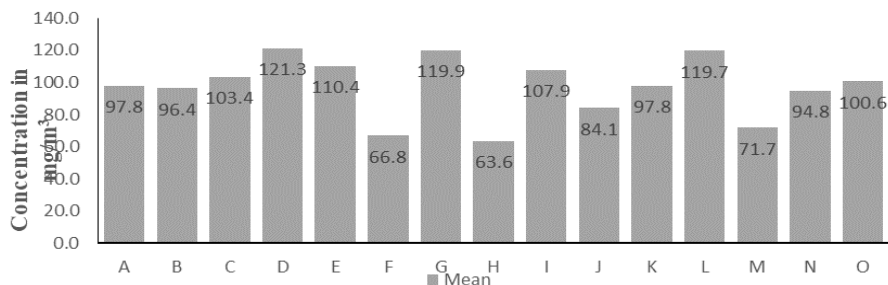


Figure 2: PM2.5 Mean Concentration of Sample Points

Figure 2 shows the mean concentration of PM_{2.5} in all the locations. They all exceeded the WHO limits for PM_{2.5}. Point D (Command Junction), G (Refinery Junction) and I (Millenium city) show a higher concentration than the other sample points which may be as a result of traffic congestion and movement of trailers and tankers and ongoing construction in Kaduna Millennium City. The result agrees with many other studies of fine particulate matter concentrations in urban Africa which demonstrate that pollution levels often exceed international guidelines (Katoto et al 2019). Annual mean levels of coarse and fine particles from short and long term air monitoring studies across urban Africa demonstrates that pollution levels often exceed international guidelines (Patrick and Kinney 2013). Also, Rasa et al (2017) showed that there is a strong positive correlation between the number of heavy diesel vehicles on the road and the concentrations of PM_{2.5} and high correlation between the motorized traffic intensity and PM_{2.5} pollutions which show similarity to this study.

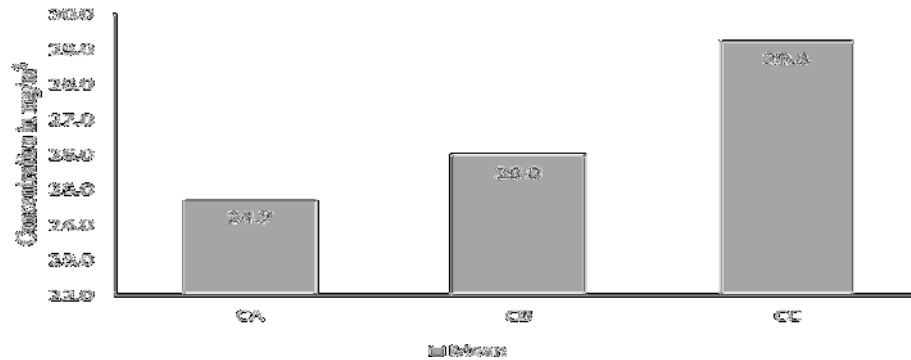


Figure 3: PM_{2.5} Control Points Mean Concentration

Figure 3 show that all the sample points exceed the control points. The highest of the control point is Lugard Hall (CC) and the least Barnawa GRA (CA). Previous studies have noted that control points usually exhibit lower pollutant concentrations than sample points, for example Zagher and Nwaogozie (2015) who assessed roadside air pollution in Port Harcourt Nigeria

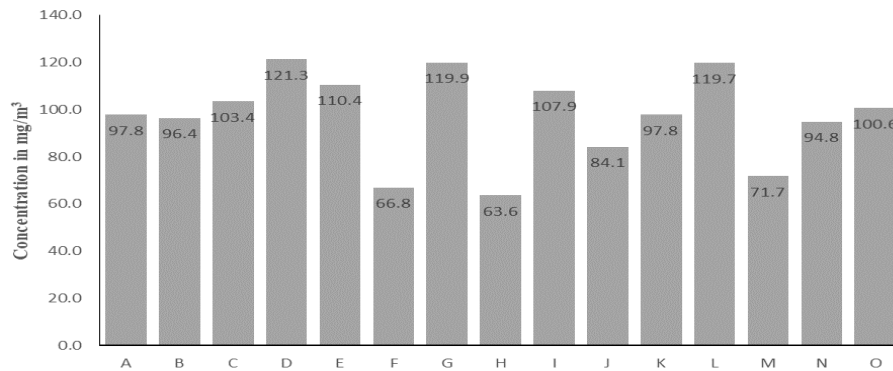


Figure 4: PM10 Mean Concentration of Sample Points

The figure 4 shows the mean concentration of PM10 in all the sample points. Point D (Command Junction) and G (Refinery Junction) shows a higher concentration which are above the standards of both NESREA and EPA. Point H (Ungwan Rimi Bus stop) shows the least mean concentration within Kaduna Metropolis. The highest points might be as a result of traffic congestion and movement of heavy-duty vehicles such as tankers and trailers while the least concentration point has minimum traffic. It agrees with the study of Jan et al. (2012) on the variability of urban air quality (ultrafine particles and PM10) in Belgium. PM10 showed a strong temporal variability over longer periods and a limited spatial variability. Taiwo et al. (2015) study showed a high total concentration of PM10 concentration range of 118.3 to 132.0µg/m³. Most of the reported PM mass concentrations in Nigeria were higher than the annual World Health Organization (WHO)

standards of 40µg/m³ for PM10. Figure 5 shows that all the sample points exceed the control points. The highest of the control point is Lugard Hall (CC) with the least Barnawa GRA (CA). This agrees with the study of Zagha and Nwaogozie (2015) mentioned earlier where control points had the least mean concentration than the selected locations within the Port-Harcourt Metropolis.

Spatial Analysis

The spatial variation of the pollutants in the study area was described using Inverse Distance Weighting tool of Geographical Information Systems (GIS).

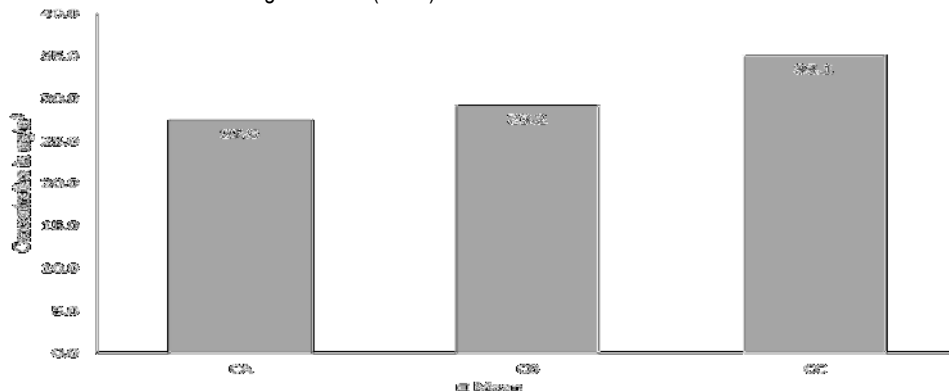


Figure 5: PM10 Mean Concentration of Control Points

standards of 40µg/m³ for PM10

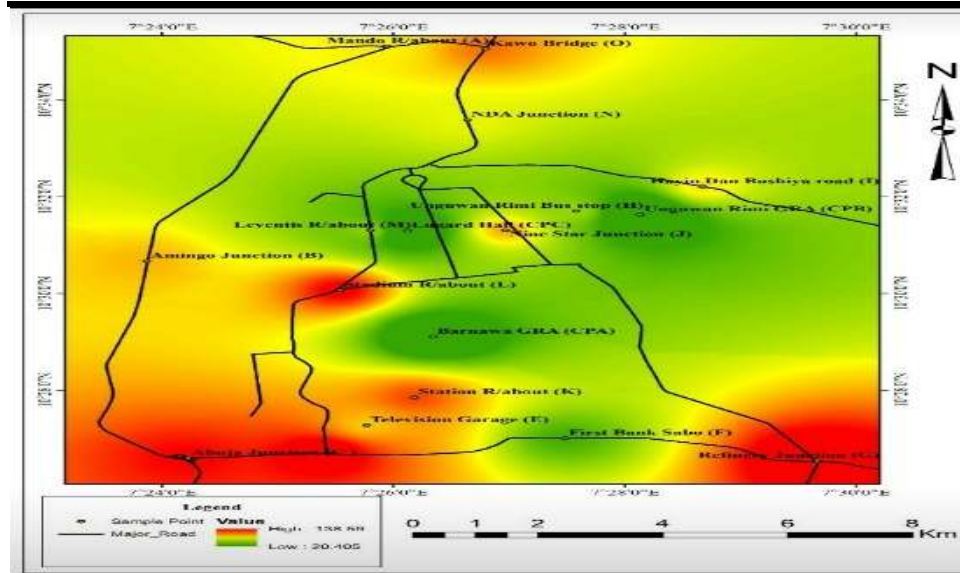


Figure 6: PM2.5 Wet Season Hotspot Mapping of the Study Area

Figure 6 shows the spatial distribution of PM2.5 during the wet season. The variation of the colour from red, orange, pale yellow and green indicates high to low concentration of the pollutants. Most parts of the study area indicate red (unhealthy level) showing high concentration with few areas showing green which indicates a safe level of these pollutants. The three control points of the sample locations within the study area show a low concentration of these pollutants.

Figure 7 shows the spatial distribution of PM2.5 during the dry season. The figure reveals more of orange and pale yellow dominates the map (study area) which indicates unhealthy level of pollutant, and is widely spread across the study area with a few areas showing green which indicates a safe level of these pollutants. It can be inferred that this is as a result of the harmattan wind. The three control points of the sample locations within the study area happened to be

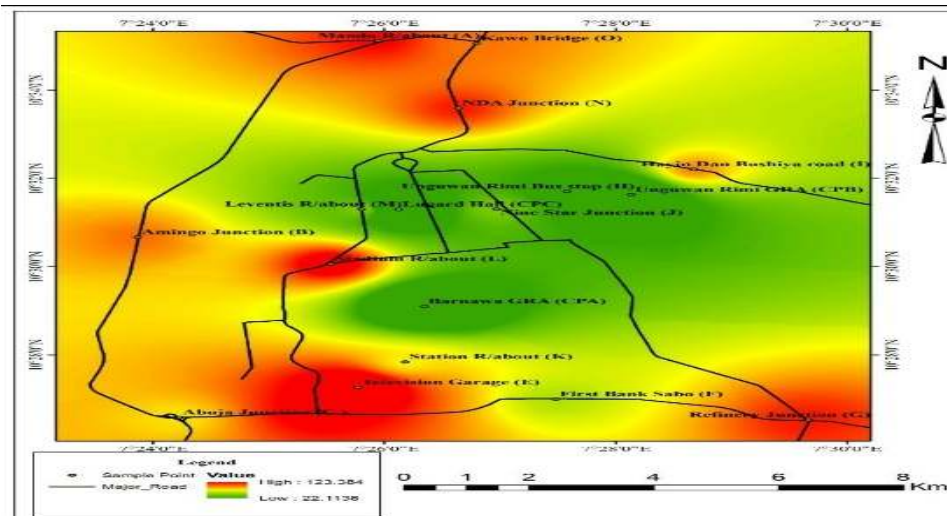


Figure 7: PM2.5 Dry Season Hotspot Mapping

areas with the low concentration of these pollutants.

map of PM 2.5, the three control points show a low concentration of these pollutants (indicated by

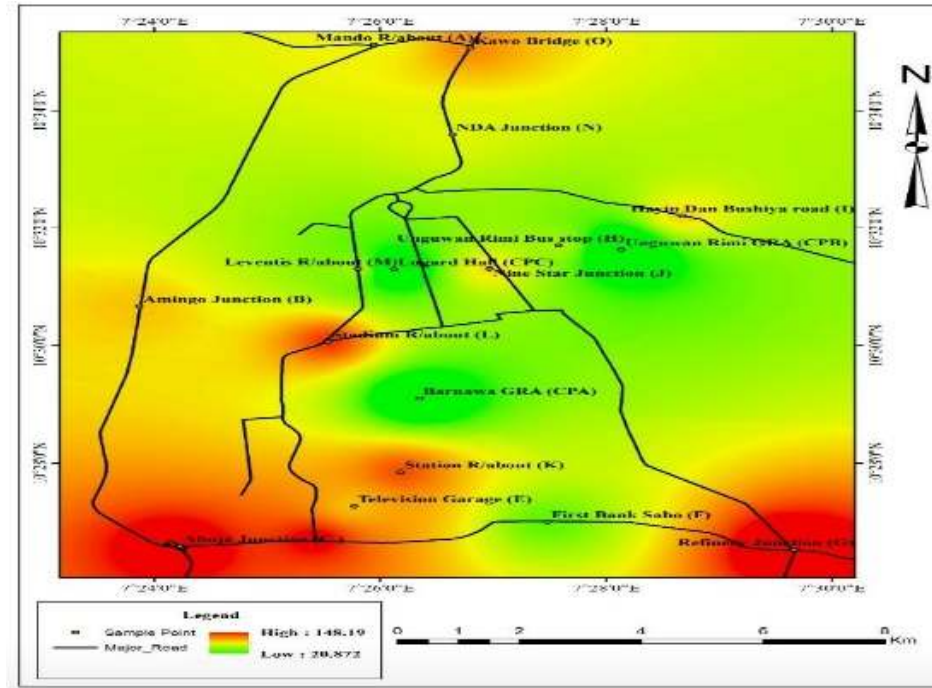


Figure 8: PM10 Wet Season Hotspot Mapping of the Study Area

Figure 8 shows the spatial distribution of PM10 during the wet season. The hotspot map reveals that a large part of the study area indicates red showing a high concentration of PM10 which is deemed very unhealthy. Some areas are green, which is the safe level of these pollutants, while there is a ring of yellow, which indicates an unhealthy level of pollutant. As with the previous

map (green). Figure 9 shows the spatial distribution of PM10 during the dry season. Though some points in the map indicate red, orange and pale yellow dominates the map which indicates an unhealthy level of PM, and this can be attributed to dust from the harmattan wind. Few areas show a safe level of these pollutants (green). Again, the control

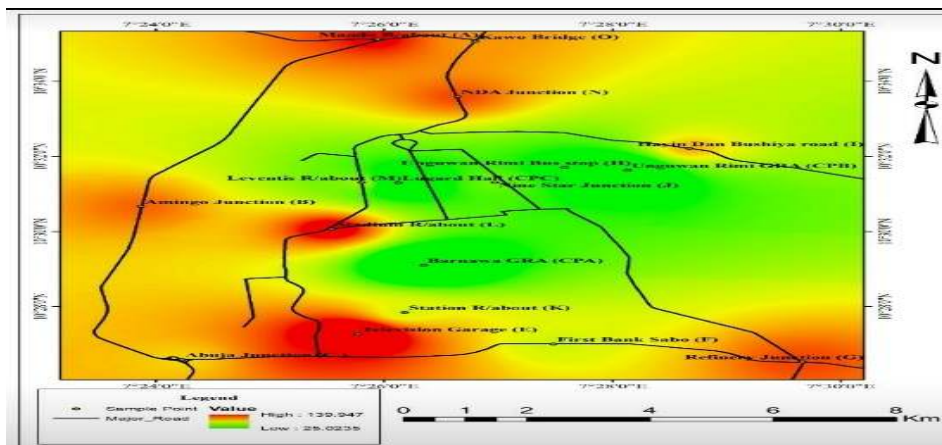


Figure 9: PM10 Dry Season Hotspot Mapping of the Study Area



points of the sample locations present a low concentration.

Results of this study have confirmed high levels PM₁₀ and PM_{2.5} along many of the sample points which conform to high traffic density areas in Kaduna metropolis, and this implies that residents and passers-by along the sample points are being exposed to an unhealthy concentration of these pollutants of concern. Pollutants exceed the EPA and NESREA standards in most of the sample locations. Persons from the control point areas like the Unguwan Rimi GRA, Barnawa GRA, and Lugard Hall, which are further away from the high traffic density and construction activities, enjoy much healthier ambient air quality. The spatial variation shows there is a significant difference in the concentration of the pollutants between the wet and dry seasons and there is an increase in the area covered by these pollutants from during the dry season. The Harmattan wind may therefore be a significant factor in the spatial variation of particulate matter pollution in Kaduna Metropolis.

CONCLUSION

The results of the study indicate that there is an urgent need to focus on air quality management in Kaduna Metropolis, given the known health impacts of air pollution, and of Particulate matter pollution in particular. An efficient and effective urban air quality management plan, comprising of systematic sampling, monitoring, and analysis; modeling; and control protocols, is necessary to manage and control urban air quality (Gulia et al 2020). This study recommends extensive tree planting to remove a significant amount of pollution from the atmosphere as part of their normal functioning. Trees improve the quality of air in the city and its surroundings and should be considered an integral part of any comprehensive plan aimed at improving overall air quality. More awareness on the dangers of air pollution, especially particulate matter, and collective preventive measures and campaigns against air pollution is needed.

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Appendix

AIR QUALITY INDEX		
AQI	Air Pollution Level	Health Implications
0-50	Good	Air quality is considered satisfactory and air pollution poses little or no risk
51-100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups experience health effects. The general public is not likely to be affected
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected
300+	Hazardous	Health alert; everyone may experience more serious health effects