Assessment of the Particulate Matter in the Ambient Atmosphere in Ilorin Metropolis, Kwara state

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Abstract: Particulate air pollution is a mixture of solid and/or liquid particles suspended in the air. They can be classified based on natural and anthropogenic sources. Some natural occurrences like volcanic activities, storms, and forest burning leads to air pollution. Anthropogenic activities are due to human activities, which includes industrial sources, personal, utility.

Particulate matter can also be classified into primary and secondary pollutants. Primary pollutants form through natural and anthropogenic conditions. Secondary pollutants include SO2, NO2, VOC, and NH3.

High exposure to particulate matter affects everything in nature—human's health, plant's produce, and material's economic values.

This research was carried out to measure the level of pollution in Ilorin Metropolis to study the concentration of common particulate pollutant—PM1.0, PM2.5, PM10 and TSP. The sampling site can be classified classified as industrial, commercial and residential areas. The study shows how dominating human activities in each environment influences particulate air pollution.

Keywords: particulate matter, pollution, air pollution, PM1.0, PM2.5, PM10, TSP, exposure, natural, anthropogenic, primary pollutants, secondary pollutants.

INTRODUCTION

The urbanization and industrialization of nations have influence on the ambient atmospheric air purity. This has led to a number of air pollution awareness and the determination of the quantity and quality of air pollutants in the ambient atmosphere. Air pollution can be defined as the introduction into the atmosphere of substances and gas that have negative effects on the ecosystem (Pierzynski *et al.,* 2005). A particular substance is considered as an air pollutant only when its concentration is relatively high compared with the background value and causes adverse effects.

Particulate air pollution is a mixture of solid and/or liquid particles suspended in the air. Some of these particles are large enough to be seen as dust or dirt, while others are so small, they can only be seen using a powerful microscope. These are of two major size ranges, known as PM_{10} and $PM_{2.5}$. PM_{10} and $PM_{2.5}$ are the most widely studied, both at major emissions sources and in ambient air. PM_{10} includes particles that have aerodynamic diameters less than or equal to 10 microns (µm) and $PM_{2.5}$ is the subset of PM_{10} particles that have aerodynamic diameters less than or equal to 2.5 µm. Coarse particles, or the subset of PM_{10} that is larger than 2.5 µm, their spatial impact is typically limited due to tendency to deposit on the ground downwind of emissions sources.

Generally, the sources of particulate matters can be natural and anthropogenic. Natural sources include volcanic activities, burning forest, storms etc.; anthropogenic sources include industrial sources, utilities, personal sources (Boubel, *et al.*, 2013). Furthermore, Air pollutants can be divided into two categories, namely, primary pollutants and secondary pollutants. Primary particulate matter sources are derived from both human and natural activities. A significant portion of particulate matter sources is generated from a variety of human (anthropogenic) activity.

Primary particulate matter sources directly emit air contaminants into the atmosphere that form or help form PM. Hence, these pollutants are considered as precedencies to PM formation. These secondary pollutants include SO_2, NO_2, VOC, and NH_3.

The environmental effects of high particulate matter presence in the ambient atmosphere include occurrence of acid rains, eutrophication of water bodies, decrement of visibility (by haze, mist and fog) occurs, ozone depletion, crop and forest damage global climate change. Furthermore, high toxic exposure of animals contributes to their birth defects, reproductive failure, and disease in animals.

LITERATURE REVIEW

Air pollutants can be classified as either primary or secondary pollutants (Daly & Zanetti, 2007). Primary pollutants are substances that are directly emitted into the atmosphere from their sources. The main primary pollutants known are carbon compounds (such as CO, CO_2, CH_4, and VOCs), nitrogen compounds (such as NO, N_2O, and NH_3), sulfur compounds (such as H2S and SO_2), halogen compounds (such as chlorides, fluorides, and bromides) and particulate matter. According to WHO (2000), secondary particles are the particles produced by the intermediate reactions of gas in the atmosphere. Examples of this include NOx, Ozone (O_3) SO_X, Sulfates and nitrates aerosols, Organic aerosols (source this)

Air pollutants can also be classified in to categories of particulate matter and gaseous pollutants (nitrogen oxides, carbon monoxide, unburned hydrocarbons, sulfur dioxide) (Flagan & Seinfeld, 2012).

articulate matter is a suspension of a complex mixture of liquid and solid particles in the air that are of different sizes, compositions and concentrations (Tippayawong, Pengchai & Lee, 2006). The chemical composition of particulate matter varies based on their sources and their dispersion conditions (Chow, Watson Edgerton & Vega, 2002). Particulate matter includes asbestos, dust, fly ash, metals, soot etc. present in the atmosphere in a concentration and for a period of time which made it harmful to the habitant (Obafemi, Eludoyin, & Akinbosola, 2012). According to WHO (2000), airborne particulate matter represents a complex mixture of organic and inorganic substances. Their mass and composition can be divided into two principal groups; coarse particles mostly larger than 2.5 μm in aerodynamic diameter, and fine particles mostly smaller than 2.5 μm in aerodynamic diameter ($PM_{2.5}$). Due to the complexity and the importance of particle size in determining exposure and human dose, numerous terms are used to describe particulate matter.

Numerous terms are associated with particulate matters. This is due to complexity characteristics and nature. One of these terms is aerosol. Aerosol is any solid or liquid particle of aerodynamic diameter ranging from 0.01μm or less, up to about 100μm. Aerosol and particles can be used interchangeably to refer to airborne particles (Abhishek & Jeremy, 2010). Atmospheric aerosols are complex mixtures of crustal matter, organic materials, and secondary products, such as sulfate and nitrate (Zhang, Sun, Zhuang, & Xu, 2006). Commonly used domestic aerosol products are insecticides, air fresheners and perfumes. Domestic aerosols are consumer aerosol products that are dispersed under pressure from disposable containers (Adeniran, Jimoda, & Sonibare, 2014). Aerosols differ in term of particle size and density and also their impact as pollutants.

Another term is suspended particulate matter (SPM), these are particles less than 10 mm in aerodynamic diameter and are often referred to as 'inhalables' (Ormstad, 2000). AQEG (2005 as cited by Thorpe & Harrison 2008) reported that the size, in diameter, of the coarse fraction of PM10 particles ranges between 2.5μm and 10μm. Others include

- Dust: these are particles that range from 1-20μm (RAO, 2006). They are predominately larger than those found in colloids and temporarily suspended in the air or gases generally.
- Smoke: these are the particles, liquid or solid, of the sizes ranging from 0.01 and 0.1 μm formed by combustion or other chemical processes (RAO 2006). Their major constituents are carbon particles.

2.2 Sources of particulate matter

Particulate matter forms from many two main sources: naturally and due to human anthropogenic activities. According to the European Environment Agency (2012), a pollution source can only be considered as a natural source if it does not involve directly or indirectly human activities.

2.1 Natuaral sources

Naturally occurring event like volcano is major source of air pollution. Eruption of volcano causes emission of particulate matter and gaseous pollutant such as SO2, H2S, and methane. The thermodynamic conditions in the volcanic edifice (pressure, temperature) and the type of magma determine the amount and composition of volcanic emissions (EEA, 2012).

Another major source of particulate matter in nature is sea salt aerosol. The result and consequence of wind stresses on water body like ocean i.e., bubble bursting at the ocean surface or sea is sea water aerosol particles (D O'Dowd & De Leeuw, 2007). Hoppel, Frick, & Fitzgerald, 2002, explained that 'air entrained through wave action form bubbles that rise to the surface and burst. As the bubble penetrates the ocean surface a liquid film is formed. It breaks and produces a number of liquid droplets that evaporate to form sea-salt solution. As the bubble collapses a water jet emanates from its center. As this jet breaks up, larger droplets are formed and evaporated to produce additional coarse-size aerosol. Seawater drops and dry sea salt particles combine to form the sea salt aerosol (Lewis & Schwartz, 2004). Sodium Chloride (NaCl) is the main component of sea salt with traces of magnesium (Mg) and sulphate (SO42-). Sea-spray particles range from particle sizes less than P.M1.0 up to PM2.5 and thus contributes to the concentration of PM10 in the air.

Forest is another major source of particulate matter in nature. Studies have indicated how vegetations improve air quality in several ways. One of which is their ability to intercept atmospheric particles and absorb various gaseous pollutants present in the atmosphere (Khan & Abbasi, 2001). However, they can also contribute to air pollution through the emission of volatile organic compounds (VOCs) which can react in the atmosphere to form ozone in the presence of nitrogen oxides (NOx) (Cavanagh, Zawar-Reza, & Wilson, 2009). The ability of tress to enhance or deteriorate air quality depends on ambient air pollution concentration, amount of healthy leaf area, the relative significance of energy reduction in decreasing air pollution, and the contribution of trees to air pollution (Cavanagh, Zawar-Reza, & Wilson, 2009).

Furthermore, another mode in which trees introduce particulates into the atmosphere is by the mechanism of opening of anther (or dehiscence). The release of pollens varies across different plant families. A major and common instigating agent is the change in atmospheric humidity which thus leads to hygroscopic shrinkage and rupture of the anther wall. Pollen grains are ultimately released into the atmosphere by wind (Vogel, 2013).

Particulate matter disperses and accumulate through the wind. Natural particles that are transported from dry regions i.e., re-suspended and transported (wind-blown) desert dust particles that have a strong impact on atmospheric visibility and aerosol composition and on particulate matter levels (EEA 2012). Other categories of air contaminant release are fugitive dust resulting from the wind erosion of contaminated soils particles; volatilization release from covered landfills (with and without gas generation), spills, leaks, and land forming Lagoons (Boubel, et al., 2008).

2.2.2 Anthropogenic sources

Emissions from vehicles, industries as well as fumes from combustion of fossil fuel from domestic activities like heating and cooking are primary anthropogenic sources (Kothai, Saradhi, Prathibha, Hopke, Pandit & Puranik, 2008). The study by Fraser (1999 as cited by Owoade, et al., 2012) reported that secondary anthropogenic sources are sources in which their means of generating pollutants involve chemical transformation of the primary pollutants by complex photochemical reactions and gas-to-particle conversion of precursors such as SO2, NO2 and Volatile Organic Compounds (VOCs) under favorable meteorological conditions (Owoade, et. al, 2012).

Another type of anthropogenic source is the anthropogenic biomass combustion, which is a major source of organic particulate matter (Saarikoski, et al., 2008).

Fugitive dust from tilling, roadways and civil engineering construction activities are also sources of particulates and can be classified as geological anthropogenic source (Kothai, et al., 2009). Mining operations also contribute substantially to the generation of particulate matter present in the atmosphere (Kakosimos, Assael, Lioumbas, & Spiridis, 2011).

Utilities usage also contributes to the pollution of the atmosphere. Modern men highly depend on utilities to the extent it's hard to imagine his survival without them. Appliances have both positive and negative effects on the environment we reside. It is easy for citizens to point out the utility as an air pollution source without connecting their own use of the power to the pollution from the utility. These substantial emissions by each appliance accumulate and become a major contributor to the particulate concentration in the atmosphere (Vallero, 2014).

Other significant types of utilities whose process of usage poses threats to good air quality are those used for waste management. Operating a sewage treatment plant poorly can cause air pollution problems. Furthermore, overloading or poor designing of these facilities and will arouse citizens to demand immediate action. In many countries open refuse/waste dump which is the most primitive way of waste management, still exist. These waste materials when burnt in the open air and consequently cause the release of harmful plumes of smoke and fumes. Landfills also cause the release of pollutants like dust and smoke.

2.3 Effects of air pollutant:

The effects of the particulate matter is immense and it affects everything present in nature– humans, plants, and the atmosphere. Exposure to particulate matter affect human health badly. There is no threshold value for particulate matter exposure below which no adverse health effects are expected. The effect of particulates on health ranges from unnoticeable chemical and biological changes to an extent of troubled-breathing and coughing. These effects are highly influenced by factors like concentration and nature of the pollutants, state of the health and age group of the receptor, exposure duration and individual genetics (H.V.N., 1989). Total human exposure to particulates, also called time-activity pattern can be determined by the concentrations found in both outdoors and indoors in the different places and the time spent in each of these environments (Perez Padilla, Schilmann & Riojas-Rodriguez, 2010). The effects of particulates on health are estimated based on dose-response equations (Aleksandropoulou & Lazaridis, 2017). Studies have established that particles are deposited in a fairly characteristic manner depending on the relationship between aerodynamic diameter of particulates, local air speed and the residence time (Tiwary & Colls, 2009). Common respiratory disease are mouth breathing tidal volume of PM. Inhalation of organic dust leads to brown lung diseases and silica dust causes silicosis (Narayanan, 2007). Furthermore, particulate matter are characterized by the aggravation of existing respiratory and cardiovascular diseases, damage to lung tissue, alteration of the body's defense systems against foreign materials, carcinogenesis and premature mortality (Jimoda, 2012). Airway resistance is the consequence of presence, most especially when the concentration is high, of irritating substances which lead to breathing difficulty (Davis, & Cornwell, 2008). Substance like asbestos is a type of particulates that can be found in many human enterprises like schools, playing grounds, industries. It is known to be highly toxic and when inhaled can cause asbestosis, mesothelioma, and lung cancer (Vallero, 2014).

Effect on vegetation and plant

Vegetation reacts with air pollution over a wide range of pollutant environmental and concentrations conditions. Factors that influence the result are the plant species, age, nutrient balance, soil conditions, temperature, humidity, and sunlight (RAO and RAO 1989). According to the US Department of Agriculture, the effect of air pollutant on plant can be injury or damage. Injury is any observable alteration in the plant when exposed to air pollution. Damage is defined as a loss in the aesthetic or economic quality of plant due to interference of pollutant (Vallero 2014). Furthermore, Ontario Ministry of Agriculture, Food and Rural Affairs (2016) stated that air pollutants that are injurious to vegetation can be classified as either local or widespread.

Local pollutants are those emitted from a specific stationary source and result in a well-defined zone of vegetation injury or contamination. Widespread pollutants consist basically of oxidant. Ozone is a component of oxidants and it is produced in the atmosphere during a complex reaction involving nitrogen oxides (NO_x) and reactive hydrocarbons, components of automobile exhausts and fossil fuel combustion. Gaseous air pollutants (NO_x, SO_x and CO_2) enter the plant directly through the stomata of the foliage while the solid particulates are absorbed on the surface of the plant. Suspended particulate deposition of foliage causes a number of damages to leaf functions viz;

decreasing chlorophyll present and consequently decreases photosynthesis, interruptio up n in gaseous exchange due to clogging of stomata by dust particles, dust deposition causes changes in the soil properties that support the plant grow.

Effect of pollution on environment

Observations and model calculations have revealed that the increase in the atmospheric aerosol burden is delaying the global warming expected from the increase in greenhouse gasses (CO_2, CH_4, N_2O, halocarbons).

Some common on consequence of high volume in the atmosphere are:

Acid rain: Unpolluted rain is naturally acidic due to CO_2 presence in the atmosphere being dissolved in it. Air pollution can change the water cycle by adding particulate matter on which water condenses. The consequence of this is acid rain.

Smog formation: There are two major types of smog based on mode of formation–classical and photochemical. Classical smog is characterized by high levels of SO_2 and smoke particulate which build up under stagnant weather conditions for a number of days (3 days and more).

Photochemical smog is the complex mixture of products formed from the interaction of sunlight with major automobiles, nitric oxide (NO) and hydrocarbons. Some factors influence photochemical reaction in nature, these include light intensity, hydrocarbon reactivity, ratio of hydrocarbon to nitric oxide, light absorber, intensity of atmospheric inversion, the mixing height (RAO, 1989).

Economic effects of air pollution

The most injurious long-term impact of PM can be proved to be the environmental consequences of reduced biodiversity and the loss of ecosystem goods and services (Grantz, Garner, & Johnson, 2003).

There are five mechanisms of deterioration that are associated to air pollutions

Abrasion: particulates of sufficient sizes that are travelling at high velocities can cause abrasive effect on materials (RAO, 1989).

Deposition and removal: particulate matter can impose threat to the aesthetic quality of material surface (RAO, 1989). However, frequent removal of pollutant by washing or cleaning of the material surface will cause a noticeable deterioration.

Direct chemical attack: some air pollutant can react directly and irreversibly with materials to cause deterioration (RAO, 1989).

Indirect chemical attack: some pollutants can be absorbed by certain material and get damaged after the pollutants have undergone chemical reactions (RAO, 1989).

Corrosion: The action of air pollutant on some material causes electrochemical process. A good example is the rusting process of ferrous metal (RAO, 1989). This is influenced by the presence of moisture.

Factors influencing atmospheric deterioration are moisture, temperature, air movement and sunlight (RAO, 1989).

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

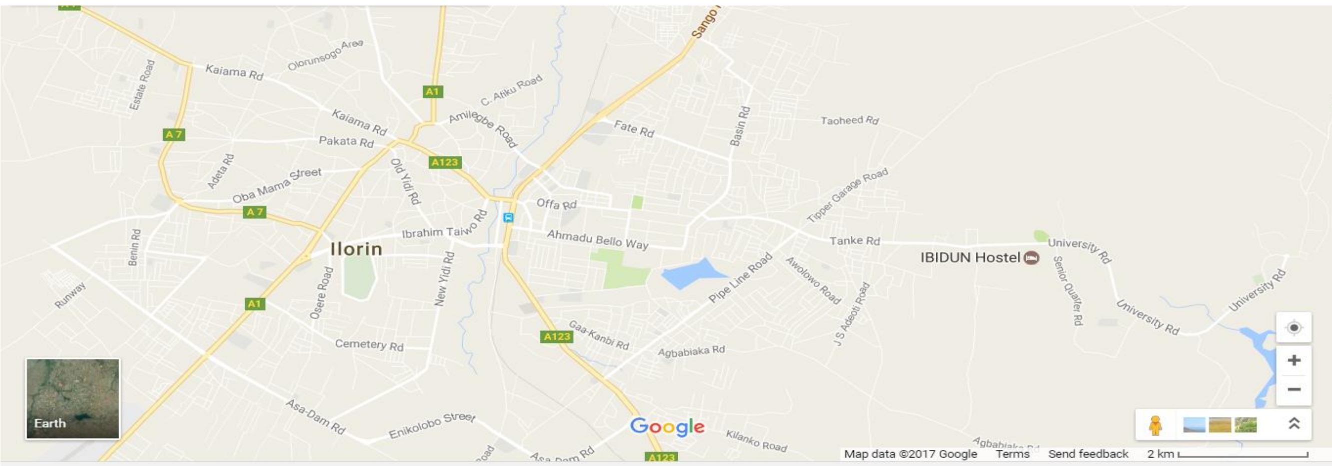
3.1 Description of sampling site

Ilorin is a city in Kwara state, North-central of Nigeria and also the capital of the state. Its geographical coordinates are on longitude $4^{o}35'$ East and latitude $8^{o}29'$ North with a relief of 305m above the sea level (Olofintoye, 2007). According to the National Bureau of Statistics (2006), Ilorin has a total population of 777,667; it's the 6th largest city in Nigeria by population. the average daily temperature range is between 25^{o}C and 35^{o}C.

The monitoring was conducted within and across Ilorin metropolis. The criteria for the selection of sampling areas are; the degree of commercial activities, volume of traffic, level of industrial activities, and population of residents. Based on these criteria the sampling sites are classified as industrial, commercial and residential areas. The sampling area and coordinates of the sampling stations are in table 3.1

Table 3.1: Names of the Sampling Locations

AREA OF SAMPLING	SAMPLING STATIONS CODE	COORDINATES	
RESIDENTIAL AREA		Longitude	Latitude
SENIOR STAFF QUARTERS ADEWOLE ESTATE OKE-ODO	R1 R2 R3	8.471^{0}N 8.480^{0}N 8.479^{0} N	4.643^{0} E 4.566^{0} E 4.629^{0} E
COMMERCIAL AREA			
TAIWO ROAD CHALLENGE UNITY ROAD IPATA MARKET	C1 C2 C3 C4	8.545^{0} N 8.483^{0} N 8.481^{0} N 8.499^{0} N	4.535^{0} E 4.563^{0} E 4.556^{0} E 4.562^{0} E
INDUSTRIAL AREA			
DANGOTE, TUYIL & KAM WIRE COCA-COLA SAW-MILL	I1 I2 I3	8.474^{0} N 8.470^{0} N 8.471^{0} N	4.533^{0} E 4.561^{0} E 4.528^{0} E



R2

Figure 3.1: Map of Ilorin showing the sampling locations

3.2 Description and Uses of the Equipment

The most important equipment used is the Met One Aerocet 531S. It's a small hand-held, completely portable and battery-operated device. The unit provides for both mass concentration of particulate matter measurement and particle number counts. It is capable of storing data-logged values, displaying real time and printing results as well as transfers these records to computer via USB. The unit measures six mass ranges including, $PM_{1.0}$, $PM_{2.5}$, $PM_{4.0}$ PM_7, PM_{10} and TSP and number concentration of particulates sizes (>0.5, 1.0, 5.0 and 10.0 microns). The mass concentration range is 0-1000μg/m^3 and the particle number concentration range is 0-3,000,000 particles/ft^3. The device duration of measurement is 1-minute interval. . It principles of operation are scattered laser light and a proprietary algorithm. Perhaps, accommodates special particulate with different densities user–programmable "K-factors". The accuracy of the device is ±10% and it sensitivity is 0.5μm.

3.3 Quality Control and Assurance

In this project work, quality control activities were taken to cognizance by choosing the appropriate equipment, inspection of the equipment as well the inspection and review of data. All equipment, devices and materials used were all in in good condition throughout the sampling period.

3.4 Comparison with Statutory Limits

Toxicity potential, according to Shonibare, et al., (2005), can be expressed as the ratio of measured ambient particulate matter concentration to the statutory limit of ambient concentration.

Toxicity potential = $\frac{M_{TSP}}{S_{TSP}}$ (3.3)

Equation (3.3) is useful in determining the detrimental effects of the haulage emissions on human health, taking into consideration the ambient air quality standards of TSP by the Federal Ministry of Environment (FMENV), World Bank (WB) and that of the World Health Organization (WHO) as reported in FEPA (1991) World Bank (1998) and WHO (1979) respectively.

Where: MTSP = measured TSP
STSP = statutory limit set for TSP

Table 3.2: Statutory Limits of Particulates

Particulates	`Concentration µg/m^3				
	EPA (2012)	WHO (2010)	ASHRAE (2010)	FEMNV/ FEPA (1991)	WORLD BANK (1998)
$PM_{2.5}$	35 (24 hrs.)	25 (24 hrs.)	15 (24 hrs.)	-	-
PM_{10}	150 (24 hrs.)	50 (24 hrs.)	50 (24 hrs.)	-	-
TSP	-	-	-	250 (24 hrs.)	80 (24 hrs.)

Source: Jimoda et al. (2014)

The average daily period extrapolated concentrations of the measured TSP were computed using an atmospheric stability formula (Bashar et al., 2009; Fakinle, et al., 2013) given in Equation (3.2) as:

$C_0 = C_1 \text{ X } F$ (3.2)

where:

C_0 = the concentration at the averaging period t_0, µg/m^3
C_1 = the concentration at the averaging period t_1, µg/m^3
F = factor to convert from the averaging period t_1 to the averaging period to $= (\frac{t_1}{t_0})^n$
n = 0.28, the stability dependent exponent
t_1 = the longer averaging time, (hour)
t_0 = the shorter averaging time, (hour).

3.5 Spatial Variation of particulate matter

Spatial variation of particulate matter/mapping of particulate matter is done by creating contours using the longitude and latitude coordinates of the studied area. A contour line is an imaginary line joining points of equal value with fixed contour lines having a specific contour interval that can be represented by the vertical distance between contours. To construct the area distribution of the measured PM data, a software package "Surfer" is utilized which can be described as a full-function 2D/3D visualization, contouring and surface modeling package that runs under Microsoft Windows. Surfer is used extensively for terrain modeling, bathymetric modeling, landscape visualization, surface analysis, contour mapping, watershed and 3D surface mapping, gridding, volumetric, and much more.

Surfer 12.4.784 (2014) is a software package written for Windows XP, Vista, and 7. Surfer transforms XYZ data to create 2D contour maps, 3D surfaces maps, 3D wireframe maps, shaded relief maps, rainbow color "image" maps, post maps, classed post maps, vector maps, and base maps.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Mass Concentration Level of Particulate Matter in Variation

4.1.1 P.M$_{1.0}$ Variation

Figure 4.1 depicts the graphical representation of the mass concentration of PM$_{1.0}$ and the recorded at the study sampling area. The average 8-hour period mass concentration of P.M$_{1.0}$ measured at the various sampling locations range between 34.5μg/m^3 and 73.4μg/m^3, the minimum was observed at sampling location C4 (Ipata Market) and the maximum was observed at sampling location C4 (Senior Staff Quarters). The average mass concentration at sampling location I3 (saw mill) is the smallest with value 42.65μg/m^3 and that at R1 (Senior Staff Quarters) with the value of 68.7μg/m^3 is the highest. The standard deviation was computed to derive the error bars. The standard deviation ranges from 2.00 μg/m^3 and 8.40μg/m^3 with the minimum and maximum observed at R2 (Adewole Estate) and C1 (Taiwo).

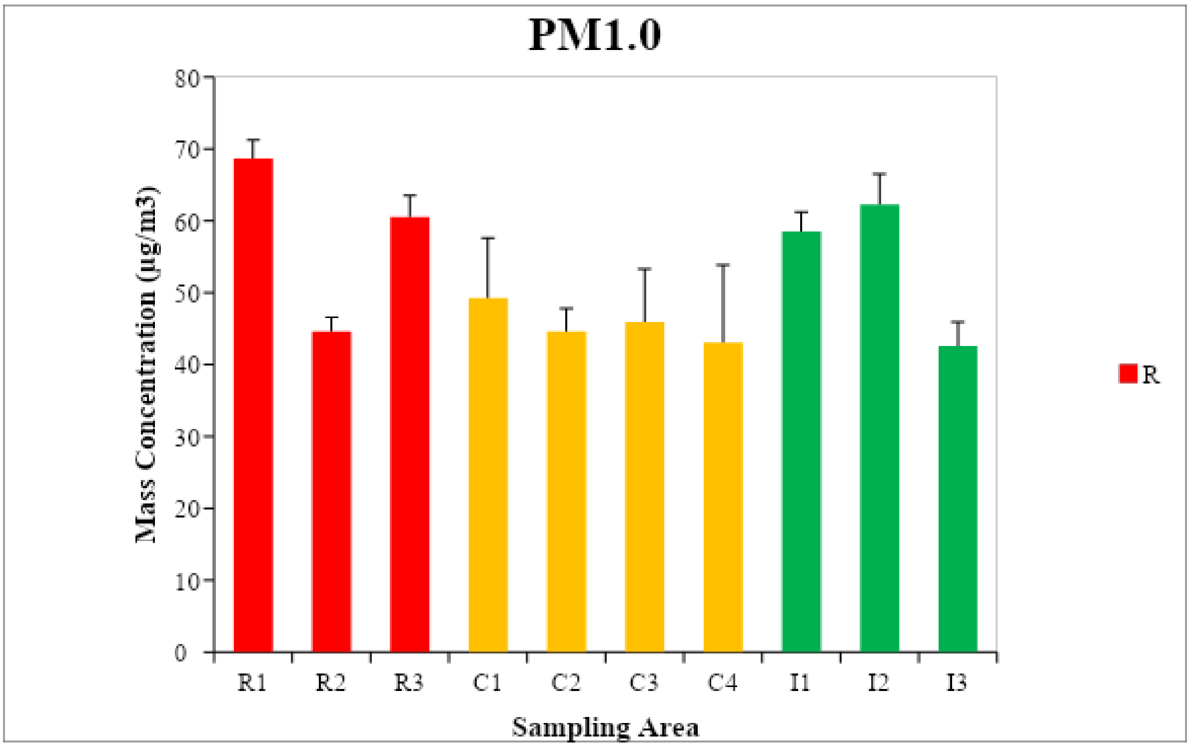


Figure 4.1: Average Mass Concentration of PM$_{1.0}$

4.1. 2 P.M$_{2.5}$ Variation

Figure 4.2 depicts the graphical representation of the average mass concentration of PM$_{2.5}$ recorded at different sampling areas. The average 8-hour period mass concentration of P.M$_{2.5}$ measured at the various sampling locations range between 103.84μg/m^3 and 562.74μg/m^3, the minimum was observed at sampling location C4 (Ipata Market) and the maximum was observed at sampling location R1 (Senior Staffs Quarters). The average mass concentration at sampling location C4 (Ipata Market) is the smallest with concentration value 121.67μg/m^3 and that at R1 (Senior Staff Quarters) is the highest with mass concentration value of 510.97μg/m^3. The standard deviation ranges from 9.77μg/m^3 and 52.98μg/m^3 with the minimum and maximum observed at C2 (Challenge) and I1 (Dangote, Tuyil & Kam wire).

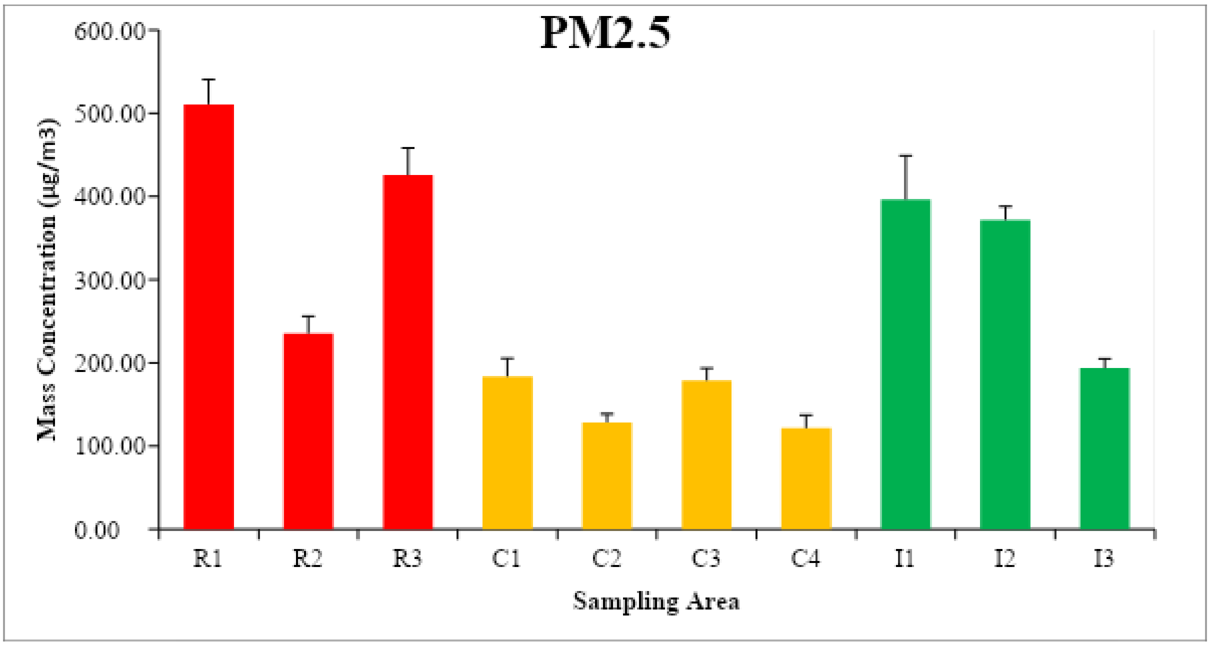


Figure 4.2: Average Mass Concentration of $PM_{2.5}$

4.1.3 $P.M_{10}$ Variation

Figure 4.3 depicts the graphical representation of the average mass concentration of PM_{10} recorded at different sampling area. The average 8-hour period mass concentration of $P.M_{10}$ measured at the various sampling locations range between 775.6µg/m³ and 6256.6 µg/m³, the minimum was observed at sampling location C4 (Ipata Market) R1 (Senior Staffs Quarters) and the maximum was observed at sampling location R3 (Oke Odo). The average mass concentration at sampling location C2 (saw mill) is the smallest with value 985.48µg/m³ and that at R1 (Senior Staff Quarters) with the value of 4681.9µg/m³ is the highest. The standard deviation was computed to derive the error bars. The standard deviation ranges from 115.89µg/m³ and 8.40µg/m³ with the minimum and maximum observed at C2 (Taiwo) and I1 (Dangote, Tuyil & Kam wire).

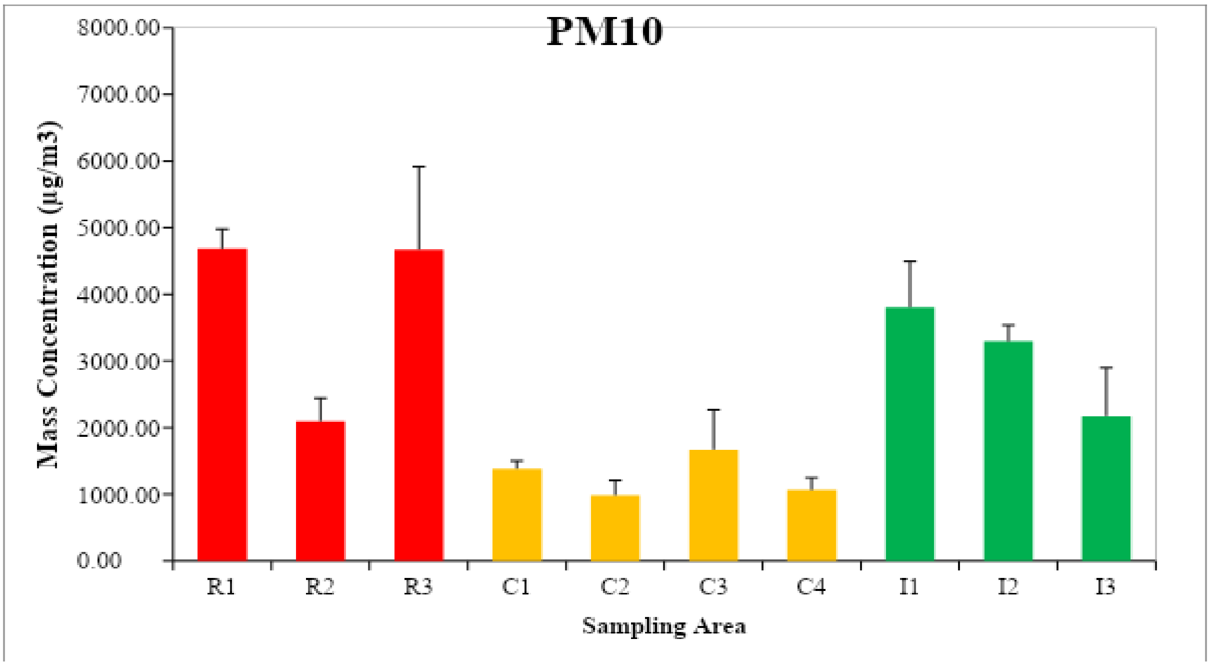


Figure 4.3: Average Mass Concentration of PM_{10}

4.1.4 TSP Variation

Figure 4.4 depicts the graphical representation of the average mass concentration of TSP recorded at different sampling areas. The average 8-hour period mass concentration of $P.M_{10}$ measured at the various sampling locations range between 1154.7μg/m³ and 9907.8 μg/m³, the minimum was observed at sampling location C4 (Ipata Market) and the maximum was observed at sampling location R3 (Oke Odo). The average mass concentration at sampling location C2 (Challenge) is the smallest with value 1107.4μg/m³ and that at R3 (Oke Odo) with the value of 6624.9μg/m³ is the highest. The standard deviation ranges from 364.77μg/m³ and 1819.35μg/m³ with the minimum and maximum observed at R1 (Senior Staffs Quarters) and I3 (Saw mill).

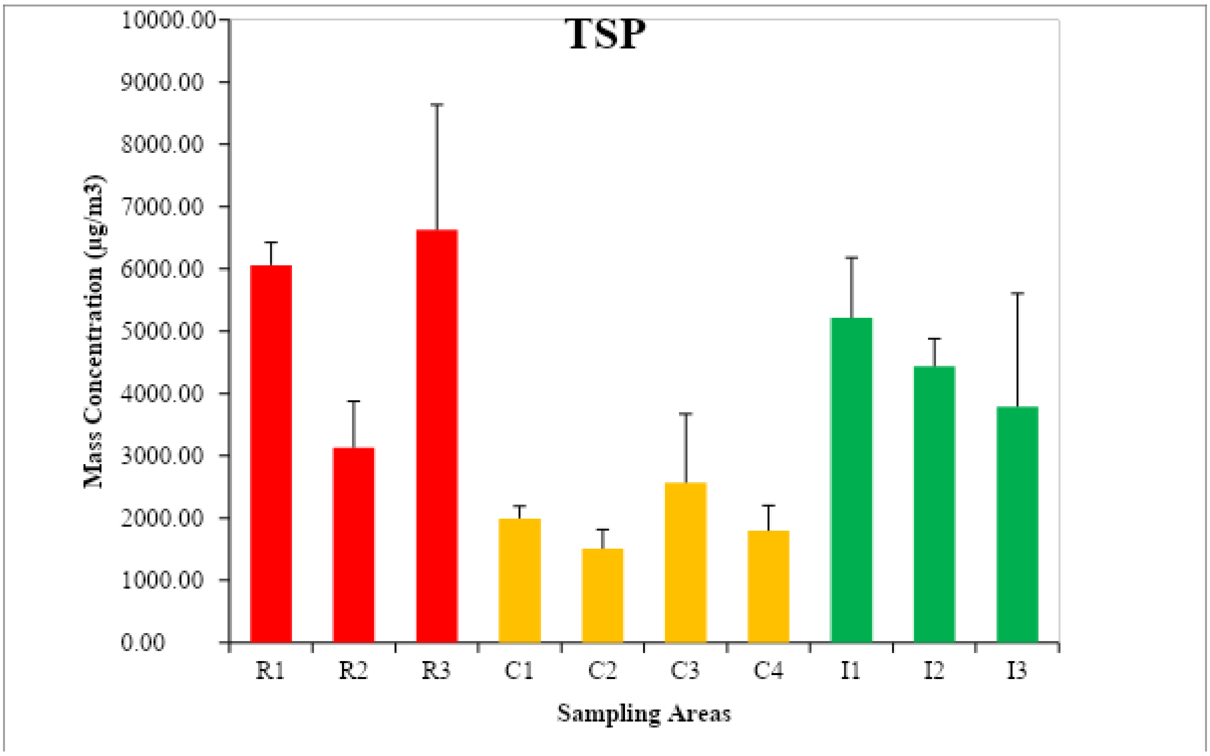


Figure 4.4: Average Mass Concentration of TSP

4.2 $PM_{1.0}$, $PM_{2.5}$, PM_{10} and TSP variation when compared with statutory limits

The concentration output of the 24-hour extrapolated values given in Figure 4.1, 4.2, 4.3 and 4.4 show that after 8 hours the concentration of the particulate in the selected sampling locations are higher than the statutory limits. The statutory limits being 35 μg/m³ EPA (2012), 25 μg/m³ WHO (2010), 15 μg/m³ ASHRAE (2010) for $PM_{2.5}$; 150 μg/m³ EPA (2012), 50 μg/m³ WHO (2010), 50μg/m³ ASHRAE (2010) for PM_{10}; 250μg/m³ EPA (2012), 50μg/m³ WHO (2010), 50μg/m³ ASHRAE (2010) for PM_{10}; 250 μg/m³ FEPA (1991), 80 μg/m³ WORLD BANK (1998) for TSP (Jimoda et al. 2014). For the 8-hour study period, the index value of $PM_{2.5}$ range between 103.8 μg/m³ and 562.7 μg/m³. The overall values of $PM_{2.5}$ were found to be in range of 121.6 μg/m³ which is moderate and 501.9 μg/m³ which is hazardous compared with the EPA Air Quality Index standard for 1999. Sampling area R1 is the largest of all the ten locations used for this study and C4 has the smallest. It is observed that the concentrations of the different particulate sizes are higher than the standard and statutory limits of different bodies. The overall average values extrapolated 24-hour index value for the particulate sizes (PM2.5 and PM10) is between 89.4 μg/m³ and 375.6 μg/m³.

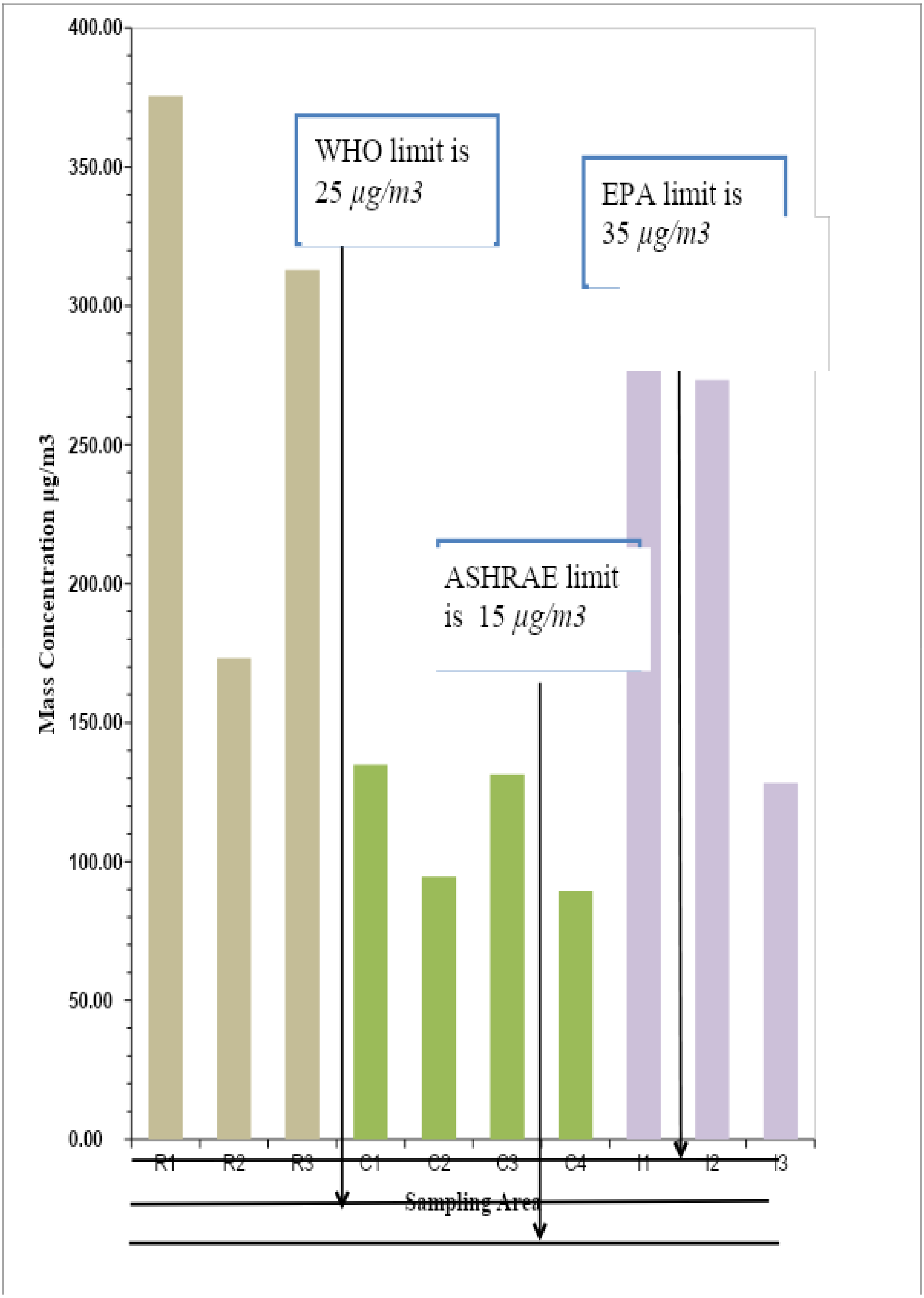


Figure 4.5: Average Mass Concentration of $PM_{2.5}$ indicating statutory limits

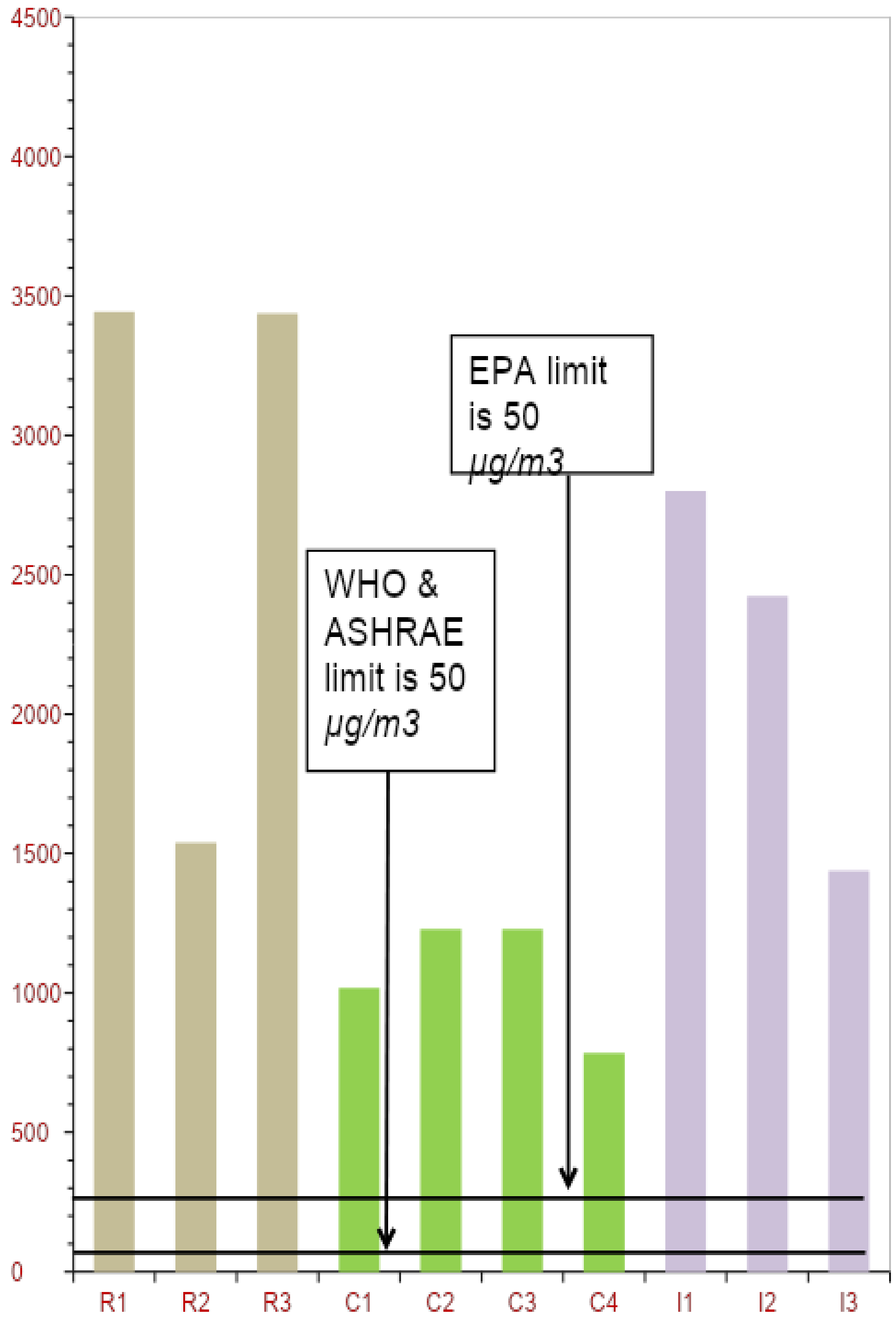


Figure 4.6: Average Mass Concentration of PM_{19} indicating statutory limits

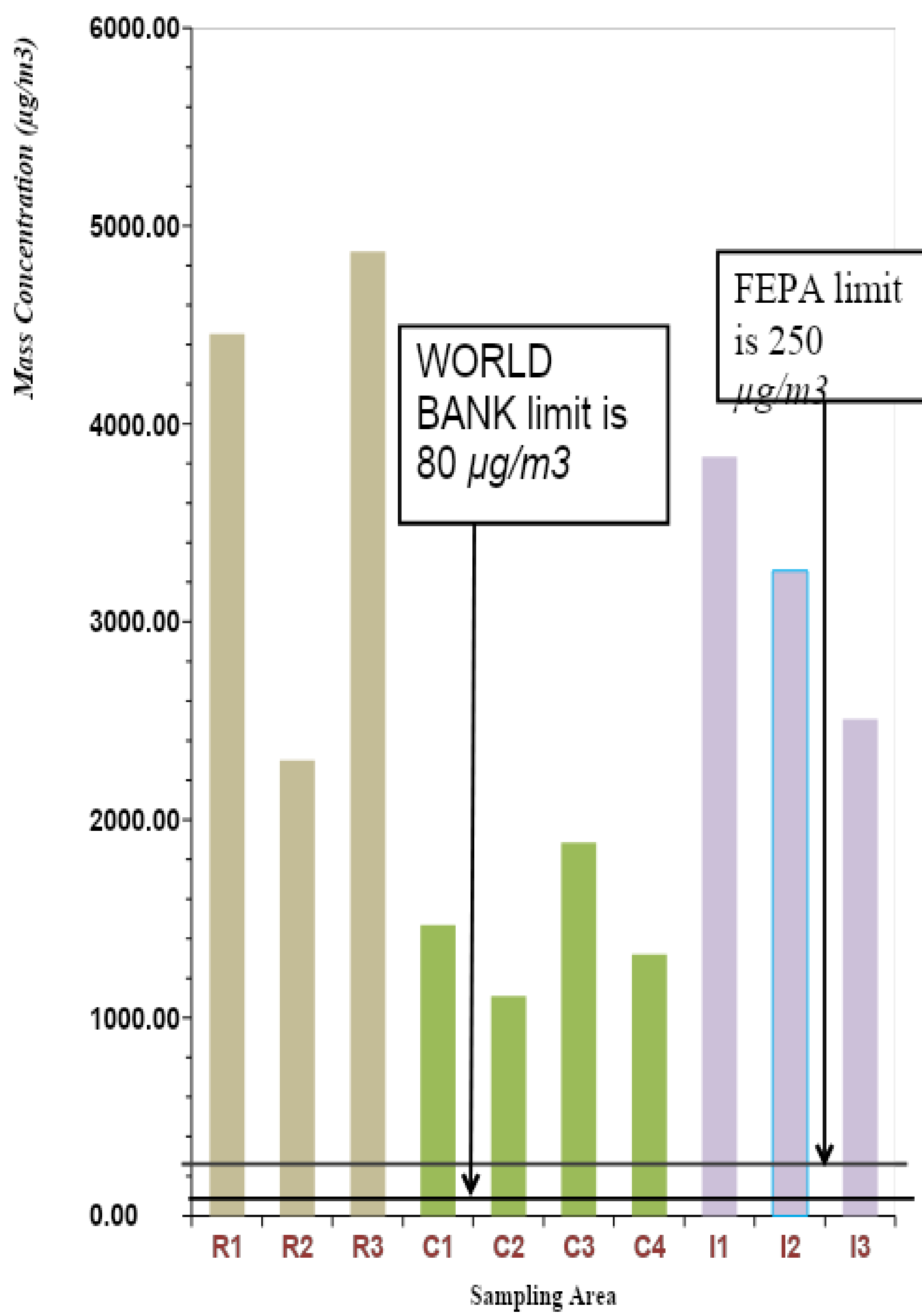


Figure 4.7: Average Mass Concentration of TSP indicating statutory limits

4.3 Spatial Variation of Particulate Matter

Figure 4.8 shows the two dimensional image of the distribution contouring for very fine PM diameter less than 1 µm ($PM_{1.0}$) within the area of study. The average mass concentration of $PM_{1.0}$ is between 42.56 µg/m^3-68.66 µg/m^3. It is density of $PM_{1.0}$ is high at the southern side of the contour map of the area of study and the central parts, but less dense at the northern. R2, C1, C3, I1, I2 and I3 fall on the northern side and R1, R3, C2 and C4 are on the southern side.

Figure 4.9, shows the two dimensional image of the distribution contouring for very fine PM diameter less than 2.5 µm ($PM_{2.5}$) in the area of study. The average mass concentration of $PM_{2.5}$ is between 121.59 µg/m^3-510.87 µg/m^3. $PM_{2.5}$ density is high at the southern and the central parts, but lower density is observed at the northern side on the contour map of the studied area. R2, C1, C3, I1, I2 and I3 fall on the northern side and R1, R3, C2 and C4 are on the southern side.

Figure 4.10, shows the two dimensional image of the distribution contouring for very fine PM diameter less than 10 µm (PM_{10}) in the area of study. The average mass concentration of PM_{10} is between 985.48 µg/m^3-4681.92 µg/m^3. PM_{10} density is high at the southern and the central parts, but lower density is observed at the northern side on the contour map of the studied area. R2, C1, C3, I1, I2 and I3 fall on the northern side and R1, R3, C2 and C4 are on the southern side.

Figure 4.11, shows the two dimensional image of the distribution contouring for TSP in the area of study. The average mass concentration of TSP is between 1507.32 µg/m^3-6624.88 µg/m^3. TSP density is high at the southern and the central parts, but lower density is observed at the northern side on the contour map of the studied area. R2, C1, C3, I1, I2 and I3 fall on the northern side and R1, R3, C2 and C4 are on the southern side.

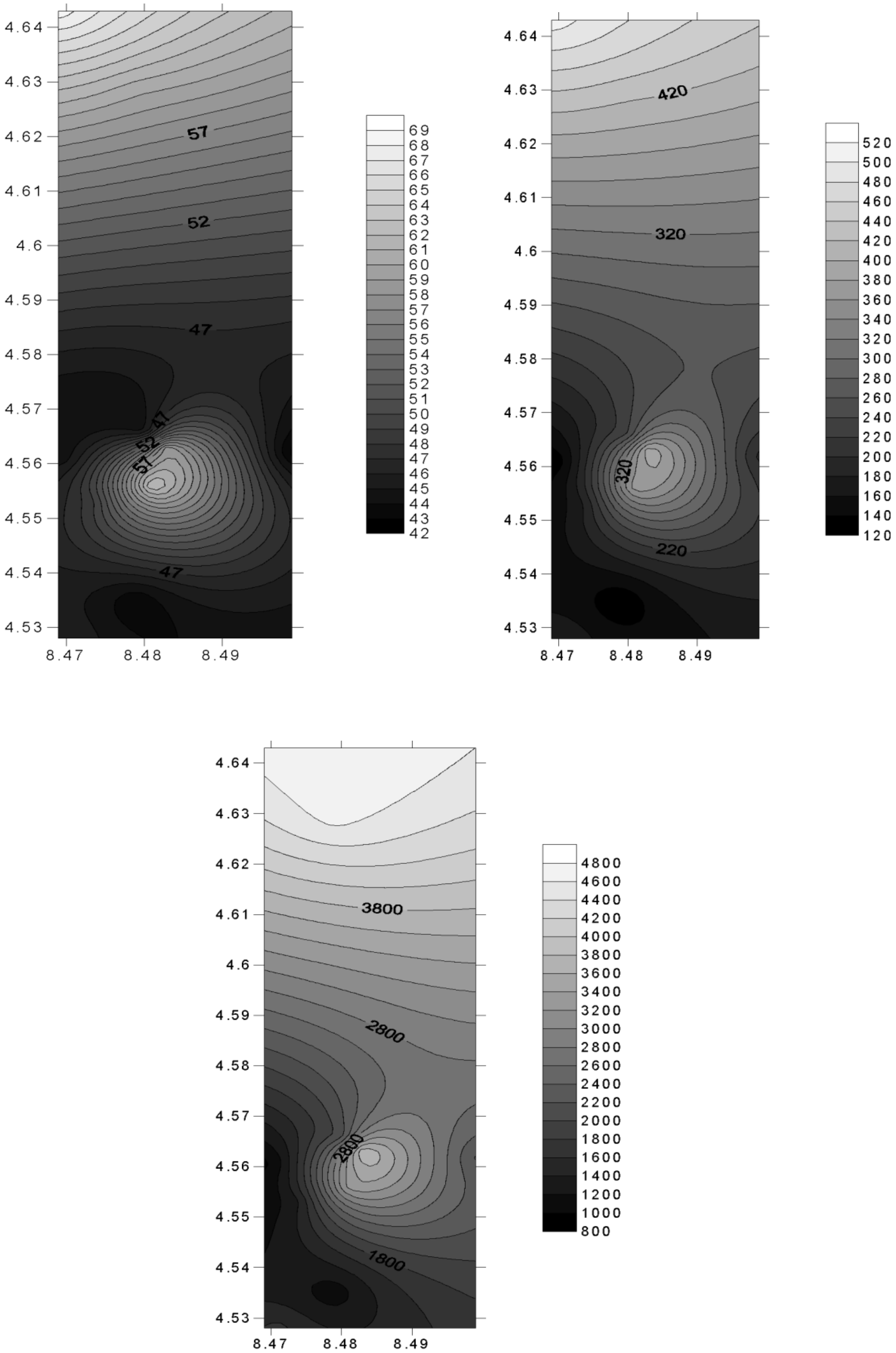


Figure 4.9: Spatial variation of $PM_{2.5}$

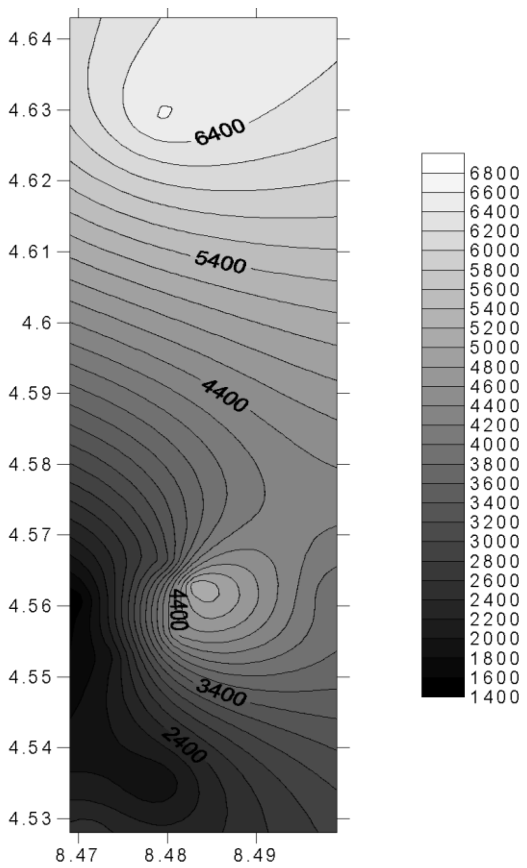


Figure 4.11: Spatial variation of TSP

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The effect of particulate matter on the habitants and the environment cannot be over emphasized. On humans, it could cause chronic health disorder and consequently lead to increase in mortality rate. It has been linked to environmental problems like global warming, acid rain. Moreover, deposition of particles on vegetation could cause blockage of stomata which would inhibit photosynthesis reactions. Deposition of particles on goods and services reduce their economic value.

The particulate matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}, TSP) data used in this research work were collected in December 2016 from 10 locations (Senior staff Quarter (R1), Adewole Estate (R2), Oke-Odo (R3) Taiwo (C1), Challenge (C2), Unity Road (C3), Ipata Market (C4) Dangote Kam-wire & Tuyil (I1), Coca-Cola (I2), Saw-Mill (I3)) within ilorin metropolis, Kwara state. Measurement of the mass concentration level of particulate matter in the atmosphere, the levels of mass concentration of particulate matter were compared with the air quality standards and spatial variation of particulate matter has been investigated. High levels of particulate matter were observed at all the locations. It was observed that the mass concentrations of $PM_{1.0}$, $PM_{2.5}$, PM_{10} and TSP were extreme at location R1. It was also observed that TSP is a major contributor to ambient particulate matter, especially in the coarse particle fraction.

5.2 RECOMMENDATION

Based on the finding of this research work, the legislature needs to enacted laws and incorporate policies on environmental ethics that will guide behavioral attitude of everyone towards creation of pollutants. Locations of companies shouldn't be close to residence and raw materials which will not cause pollution of the environment should be enforced. Indiscriminate release of exhaust should be shunned. Vehicle Inspection Officers should be well equipped and empowered.

This research work was done during the harmattan period and it thus shows the need for further characterization of the fine and coarse particles over a longer period of time in the whole city of Ilorin. Further work is also required on source apportionment and for the quantification of potentially detrimental components. Also, the health relevance of particulate matter concentrations during these episodes should be investigated further.

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