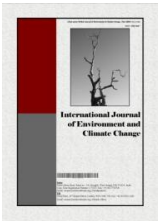

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Mass Concentration and Size-distribution of Atmospheric Particulate Matter in Plateau State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author ECH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EAT and TJI managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

The mass concentration and size distribution of atmospheric particulate matter (PM) was measured in three major towns in Plateau state. The CW-HAT200 $PM_{2.5}$, PM_{10} dust particle counter was used to measure the particle size in each major location within Jos, Shendam and Pankshin. The results revealed that both $PM_{2.5}$ and PM_{10} concentration were high in morning hours in most of the measured locations. These values were however found decreasing in the afternoon. The higher value of $PM_{2.5}$ and PM_{10} observed in the morning hours in some locations within the study area can be attributed to the high volume of motorists plying the roads during those hours. However, some locations within the study area their $PM_{2.5}$ and PM_{10} were higher in the afternoon hours than morning hours. The PM sampling respirable dust sampler (AMP460NL model) was placed on the elevated platform of 1.5 m high and 20 cm away from obstacles in order to avoid any obstruction of the air from tall buildings and trees etc. Measurements were taken after 8-hours per location and the average air flow rate, sample time, initial and final mass of the filter paper were used to calculate the mass concentration of the suspended particulate matter in each locations.

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The mass concentration of the suspended particulate matter were higher in dry season than in the rain season for all locations. This can be attributed to the dust usually experienced during the dry season on the Plateau.

Keywords: Mass concentration; size distribution; atmospheric; particulate matter; measurement.

1. INTRODUCTION

Air pollution has been identified as one of the biggest environmental risks to health. The World Health Organization (WHO) in 2012 reported that, one out of every nine deaths was the result of air pollution-related conditions [1]. There are worldwide interventions and policies for reducing air pollution issues that have worked effectively in Europe [2] and United States of America. However, the scenario is not the same in sub-Saharan Africa and Nigeria in particular.

Despite the fact that the Federal Government of Nigeria in 1992 established the Federal Environmental Protection Agency and similarly each state has set up the Agency. This Agency, apart from other functions was saddled with the responsibility of ensuring clean air quality in the country. The Agency was to formulate criteria, guidelines, specifications and standard ways of protecting and enhancing the quality of Nigeria's air resources so as to promote the public health or welfare and the normal development and productive capacity of the nation's human, animal or plant life.

However, after several years of its existence, there is no detailed analysis of air quality trends or awareness campaign in the country regarding air quality to the best of our knowledge. The lack of ambient air pollution epidemiologic data in sub-Saharan Africa and Nigeria in particular has become one major global disparity.

The World Health Organization has categorized Nigeria as a country with several worst polluted towns. That list included Onitsha, Aba, Kaduna and Umuahia. But the above mentioned cities are not the only areas with extreme particulate matter concentration ($\leq PM_{10}$) in Nigeria. Cities in Nigeria are growing rapidly, yet estimates of its impact on the region are highly underestimated due to lack of air quality monitoring, a paucity of air pollution epidemiological studies, and important population vulnerabilities in the country.

Plateau is the twelfth-largest state in Nigeria with a population of about 3.5 million people. The state is located approximately in the centre of Nigeria with an area of 26,899 square kilometers on latitude 08°24N and longitude 008°32'and 010°38'E [3]. The state is unique and popular in Nigeria due to its boundaries of elevated hills surrounding the Jos plateau, waterfalls and the mining activities which took place during the colonial era till date [4]. The inhabitants of the state are predominantly farmers and there are a lot of quarry operations in the state. Quarrying has been known to usually associate with dust particles particularly particulate matter (PM) in an environment.

Ambient air pollution has been described by the World Health Organization to be the biggest environmental risk to health, carrying responsibility for about one in every nine deaths annually. Ambient (outdoor) air pollution alone kills around three million people each year, mainly from non-communicable diseases [1]. The activities of quarry operations, farming and emissions from both motorists and burning of substances in air has continued to raise dust and other harmful substances in the atmosphere at alarming rate in Jos and its environs and other populous towns on the Plateau like Pankshin and Shendam. It has been reported that the dust particles and other substances released to the atmosphere by the activities of quarrying, farming, motorists, burning of substances in air, unpaved roads, crushing of stones, sulfur dioxide etc. are capable of affecting our economy, quality of life of people and health of the population [5-10].

In recent years, there has been a growing awareness about possible biological effects of deposition of various pollutants in the atmosphere [11,12]. Air pollution and population health has become one of the most important environmental and public health issues [13]. This is because atmospheric pollution poses a major impact both to human health and the environment. Recent research works conducted in Nigeria have shown evidences of ambient air quality being above regulatory limits in various cities in Nigeria [14,15].

The recent studies done on the effect of air pollution and diseases associated to ambient air pollution in some Nigerian cities also revealed

that sickness such as tuberculosis, cerebrospinal meningitis, pneumonia, measles, chronic bronchitis, pertussis, pulmonary, complicated coughing, sneezing and acute respiratory infection, cardiovascular diseases etc. are commonly prevalent in those cities [16-18].

The data collected from some clinics and hospitals in the study areas also revealed prevalent diseases such as complicated coughing, sneezing, allergic asthma, pulmonary, tuberculosis, pneumonia, upper respiratory tract infection, chronic bronchitis, cardiovascular diseases and visual impairment. The rain of dusts been experienced on the plateau especially during the dry season couple with the data of prevalent diseases obtained from clinics and hospitals in the study areas are the rationale behind this study.

2. THEORETICAL FRAMEWORK

2.1 The Effects of Ambient (Outdoor) Air Pollution

A 2013 assessment by WHO's International Agency for Research on Cancer (IARC) concluded that outdoor air pollution is carcinogenic to humans, with the particulate matter component of air pollution most closely associated with increased cancer incidence, especially cancer of the lung. An association also has observed the relation between outdoor air pollution and increase in cancer of the urinary track/bladder [1].

Ambient air pollution in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide per year in 2012; this mortality is due to exposure to small particulate matter of 10 microns or less in diameter (PM_{10}), which causes cardiovascular and respiratory diseases and cancers [7,8].

People living in low-and middle-income countries disproportionately experience the burden of outdoor air pollution with 88% (of the 3.7 million premature deaths) occurring from low- and middle-income countries, and the greatest burden in the WHO western pacific and South-East Asia regions [19]. The latest burden estimates reflect the very significant role air pollution plays in cardiovascular illness and premature deaths-much more so than was previously understood by scientists.

The quality of human health, nature and built environment around man largely depend on the quality of air in his environment. It has been shown that man can live for five weeks without food and five days without water, but only five minutes without air. This shows the importance of air to humans. When the quality of air is altered by pollutants, it affects both biotic and abiotic components of the environment. The particulate matter is a major class of air pollutant commonly found in an environment. Researchers have reported that it affects both components of the environment on a continuous basis. The fine particles affect health while coarse fraction affects public utility.

Nigeria, according to United Nations Economic Commission for Africa is categorized as a gas surplus Nation which has limited supply and utilization. Over 68% of the gas produced each day is flared. Most of the spilled oils in Nigeria catches fire, and may continue to burn for days such that together with the burning gas, and occasionally harmattan dust, produce fine particulate matter (PM) [20].

2.2 PM Measurement Using CW-HAT200 Model

The CW-HAT200 $PM_{2.5}$, PM_{10} dust particle counter air quality monitor was used to measure the air quality. The model which has a $PM_{2.5}$ and PM_{10} size range of 0-500 $\mu g/m^3$, uses the principle of light scattering and has a detection sensitivity of 0.001 mg. At every site the device power button was pressed and held for 3 seconds to allow it boot. The sampling port on the dust cover was then removed and temperature and humility sensor was installed. The run/stop button was pressed to start testing. Each test process takes 60 seconds to ensure sample representation is as close as possible to the average value of the surrounding air. The device then displayed the results automatically after finished testing. The same procedure was used for 25 minutes at every site and readings were taken after 60 seconds of counting. The air quality was monitored both in the morning hours and afternoon for every study area. The results for $PM_{2.5}$ and PM_{10} in each study area is shown in Table 1.

2.3 PM Sampling Respirable Dust Sampler (AMP 460 NL)

The sampler was placed on the elevated plat form of 1.5 m high and at a distance of 20 cm away from tall buildings, trees, fences etc. to avoid obstruction of the air. After setting the

sampler, marked sample bottles were weighed and fixed under the conical hopper, one at a time. Marked and pre-weighed filter papers M_1 were then clamped between the top cover and filter adaptor of the assembly of the machine. The filter cover was then closed and the sampler switched on taking note of time.

The filter papers and sample bottles were removed after 8 hours and re-weighed to obtain their weight after exposure, M_2. The volume of sampled air was obtained from flow meter reading and sampling time. The concentration of the fine coarse PM was then calculated.

2.4 Determination of Mass Concentration

The exposed filter paper from APM460 NL was then equilibrated for 24 hours in the desiccators and then weighed using electronic balance (model; 2500 Delta range). After weighing, the filter papers were preserved for chemical analyses.

Calculation was then done using the following relations:

Volume of air samples:

$$V = \emptyset T \quad (1)$$

Where V is air volume sampled,m^3, $\emptyset$ is average air flow rate, m^2/min and T is the Sample time, in minutes.

The mass concentration of suspended particulate matter were then calculated and reported to the nearest microgram per cubic meters as follows.

$$PM(\mu g/m^3) = \frac{(M_2 - M_1)\ X\ 10^6}{V} \quad (2)$$

Where PM is the mass concentration of particulate matter in $\mu g/m^3$, M_2 and M_1 are the initial and final mass per filter paper respectively in grams, V is volume of sampled air in m^3 and 10^6 is the conversion factor from grams

Table 1. The average $PM_{2.5}$ and PM_{10} concentration in microgram per cubic meter

Site	Concentration in the morning		Concentration in the afternoon	
	$Pm_{2.5}$ (Mg/m^3)	Pm_{10} (Mg/m^3)	$Pm_{2.5}$ $(\mu g/m^3)$	Pm_{10} (Mg/m^3)
Terminus, Jos North	7.32	14.64	3.55	6.85
Dilimi qtr, Jos North	7.44	15.24	7.45	15.55
Bukuru low cost, Jos South	7.76	15.52	1.30	2.40
Building material; (saboin barki), Jos South	8.16	17.20	7.10	14.85
Zaramangada, Jos Shouth	6.72	13.84	2.95	5.90
Rayfield, Jos South	4.86	9.68	1.80	3.55
Old airport junction, Jos South	5.48	11.36	3.60	7.25
Bidabidi, Jos North	36.00	75.75	6.40	13.20
Ecwa staff school, off Zaria rd, Jos North	10.84	22.56	2.90	5.90
Polo roundabout; Jos North	7.32	15.40	4.90	9.95
Tomato market (farin gada), Jos North	9.48	19.40	11.30	23.80
Faringada roundabout, Jos North	6.72	14.28	10.28	20.76
Tina junction, Jos North	7.04	14.24	8.20	16.60
Dogon dutse, Jos North	2.76	5.28	3.65	7.45
University of Jos, Jos North	7.32	14.69	6.80	13.80
Fce (bwarak), Pankshin	17.24	37.48	5.25	10.70
Opposite fce (across), Bwarak	8.32	17.64	4.68	9.36
Monday market junction, Pankshin	9.32	19.36	8.52	17.92
Check point tambes, Pankshin	7.12	14.60	4.13	8.40
State low-cost, Shendam	9.13	18.42	6.03	12.35
Shendam market, Shendam	20.04	41.11	26.31	55.08
Mikang rd junction, Shendam	15.33	32.60	20.43	40.52
Federal low-cost, Shendam	6.64	13.32	6.07	12.13

Table 1 contains the average concentration of $PM_{2.5}$ and PM_{10} as measured using CW-HAT200 at the study area

to micrograms. The results for mass concentration of suspended particulate matter PM for the study areas are shown in Table 2.

3. RESULTS AND DISCUSSION

The mass concentration and size distribution of atmospheric particulate matter (PM) was measured in three major Urban settlements in Plateau State, Nigeria. A dust particle counter (CW-HAT200 Model) was used both in the morning and afternoon hours to measure the $PM_{2.5}$ and PM_{10} in these settlements. The measurements were carried out at different locations in Jos (e.g. Terminus, Dilimi, Bukuru Low Cost, Building Materials, Zaramangada, Rayfield. Old Air Port Junction, Badabidi, ECWA Staff School, Polo Round About, Tomato Market Farin Gada, Farin Gada Round About, Tina Junction, Dogon Dutse and University of Jos), Shendam (e.g. Shendam Market, Mikan road Junction State Low cost and Federal Low Cost) and Pankshin (e.g. FCE Pankshin gate, Across, Monday Market Junction and Tambes). There are about forty sites in the study area. However, the above were considered because of their population and human activities like traffic, market etc.

The results of the average concentration of $PM_{2.5}$ for all the locations showed that Shendam Market has the highest of 23.18 $\mu g/m^3$, Bidabidi 21.20 $\mu g/m^3$, Mikan road Shendam 17.88 $\mu g/m^3$ and FCE Pankshin Gate 11.25 $\mu g/m^3$ (see Table 1). These values are extremely high considering the fact that measurements for this work were carried out in less than 2 hours at each location and the World Health Organization guidelines for $PM_{2.5}$ is 25 $\mu g/m^3$ 24-hr mean [21] and the standards set by the National Ambient Air Quality Standards of 35 $\mu g/m^3$ 24-hr mean [22]. Similarly the PM_{10} in these locations were equally high with 48.10 $\mu g/m^3$ in Shendam Market, 46.56 $\mu g/m^3$ at Mikan RD Shendam, 44. 88 $\mu g/m^3$ in Bidabidi 24.09 $\mu g/m^3$ at FCE Pankshin gate. This is also high considering the time taken for the measurement and the 50 $\mu g/m^3$ 24-hr mean specified in WHO guidelines.

The mass concentration of the suspended particulate matter was determined by exposing the filter paper from APM460 NL which was equilibrated for 24 hours in the desiccators and weighed. The calculation was done using equations (1) and (2) above. The results from the calculations revealed high PM concentration during the dry season in areas such as State Low Cost Shendam, Pankshin Monday Market, Federal Low Cost Shendam, State Low Cost Jos, Faringada and Bidabidi Jos considered high (see Table 2). This high concentration of particulate matter in dry season could be due the high farm activities, quarry operations, fertilizer, insecticide etc. dominant on the Plateau couple with the powerful harmattan wind.

The high concentration of particulate matter observed in this work could just explain why there are prevalent issues of complicated coughing, sneezing, allergic asthma, pulmonary, tuberculosis, pneumonia, upper respiratory tract infection, chronic bronchitis, cardiovascular diseases and visual impairment in the study areas.

Table 2. Mass concentration of suspended particulate matter (PM) in nearest microgram per cubic meter

Site	Dry Season (Between January & February, 2018) 8hrs	Raining Season (Between July & August, 2018) 8hrs
	PM ($\mu g/m^3$)	**PM ($\mu g/m^3$)**
FCE Pankshin (Across)	9.17	8.17
Monday Market Pankshin	21.28	8.33
Tambes	6.83	5.21
FCE Pankshin Sch. Gate	12.50	8.33
State Low Cost Shendam	22.74	13.89
GRA Shendam	9.26	6.94
Fed. Low Cost Shendam	18.94	10.42
Farin Gada Jos	13.89	12.50
Bida bidi Jos	13.89	8.33
Tina Juntion Jos	12.50	6.94
State Low Cost Jos	14.46	5.95
Bukuru Market Jos	13.89	11.79

Table 2 is the mass concentration of suspended particulate matter as calculated using equations (1) and (2)

4. CONCLUSION

Measurement to determine the air quality on the Plateau was carried out between January and February 2018 during the dry season and between July and August, 2018. These months were chosen because dust particles are predominant during the months of March and April. Similarly July and August are considered most rainy months in a year on the Plateau.

The high $PM_{2.5}$ value obtained from Shendam town could be attributed to the high usage of generators in the market for powering appliances because of too much heat in the environs and other primary and secondary source particles commonly found in the area such as cars, trucks, unpaved roads, stone crushing, burning of substances in air and the used of herbicide, fertilizer, insecticide on the farm. This can also explain why there are several cases of complicated coughing, sneezing, upper respiratory tract infection, and cardiovascular diseases in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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