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Assessment of Particulate Matter Concentrations in Aerosols from Selected Location of Kastina, Batagarawa, Kaita and Jibia Local Government Areas of Katsina State, Nigeria

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ABSTRACT: Particulate Matter have propensity to penetrate deep into the lungs, bloodstreams, and brain, making it the most dangerous kind of air pollutants, causing health concerns such as heart attacks and respiratory disorders. Thus, this research is focused on investigating the concentration of Particulate Matter ($PM_{2.5}$ and PM_{10}) in $\mu g/m^3$ of Aerosols in some locations in Katsina Metropolis using energy dispersive X-Ray Fluorescence (EDXRF) Analysis. Results obtained reveal that the average $PM_{2.5}$ concentration for Katsina Metropolis ranged from 19-67 $\mu g/m^3$, while the average PM_{10} concentration ranged from 112-192 $\mu g/m^3$, revealing that about 80% of the Particulate Matter loads in Katsina is above the WHO recommended limit. The $PM_{2.5}/PM_{10}$ ratio of Katsina metropolis (0.28) are below the WHO recommendation (0.5-0.8). Lower ratio implies higher PM_{10}, hence, Katsina Metropolitan Area is polluted with PM. Higher limits of Particulate matter in Katsina metropolis could be as a consequence of urbanization and other economic activities without due regulation and the dust particles from the Sahara blowing North to South. Therefore, relevant agencies could periodically access the levels of PM in Katsina State in other to take proactive measures for safeguarding the populace.

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Particulate matter (PM) is a complicated mixture that is usually fractionated by particle size. Particles having diameters fewer than 10 microns are referred to as PM_{10}, while those with diameters less than 2.5 microns are generally referred to as $PM_{2.5}$ (Tsai *et al* 2008). It originates from two major sources. Natural aerosolization of crustal debris, including suspended dust from roads, sea salt, and biological stuff like pollen and mushrooms, as well as fossil fuel burning (Koenig, 2000). Large, dark PM contain smoke and soot from incomplete combustion, as well PM can also contain dust. Diesel automobiles are a major cause of coarse and fine particle pollution containing the most dangerous component of automobile exhaust is particulate matter (Yeh, 2007). Two alternative size of Particulate Matter are often used in atmospheric monitoring namely PM_{10} and $PM_{2.5}$. ISO defined PM_{10} (Inhalable particles) as the "thoracic convention" in ISO 7708:1995, Clause 6; they pass through a size-selective inlet with a 50% efficiency cut-off at 10 μm aerodynamic diameter and $PM_{2.5}$ (Alveolar particles) as the "high risk respirable convention" in ISO 7708:1995,7.1. They pass a size-selective inlet with a 50% efficiency cut-off at 2.5 μm aerodynamic

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diameter (Chan *et al* 2002). Many epidemiological studies have found consistent links between ambient levels of particulate matter with an average diameter of 10 micrometres (PM_{10}) and fine particles with a diameter of less than 2.5 micrometres ($PM_{2.5}$) and adverse health effects like cough, asthma, renal failure, and infertility (Fantke *et al* 2015)**.** In metropolitan areas, $PM_{2.5}$ and PM_{10} are well-known traffic-related air pollutants, and their exposure has become a severe public health danger (Cheng *et al* 2008). Aerosols are small solid particles or liquid droplets suspended in air or another gas. They can be natural, such as fog, dust, or geysers, or artificial, such as haze, particulate air pollution, and smoke (Cheng *et al* 2008; Joseph *et al 2018*). Katsina Metropolitan Area (which comprises of Katsina Local Government Area and some parts of Batagarawa, Kaita and Jibia Local Government Areas) is witnessing significant growth in population and urbanization, especially in the past 20 years. To mitigate the consequences of urbanization, there is an imbalance between urban growth and support infrastructure. The emergence of increased urban air pollution, which has become a serious concern, is one of the repercussions. This is due to the fact that the West African sub region, where Nigeria is located, is considered to be one of the most heavily aerosol-burdened due to geo-genic particles from the Saharan desert zones and biomass-burning, both of which produce enormous amounts of soot and organic carbon. Other sources of emissions include automotive traffic, hospital, industrial, and domestic trash incinerators, the burning of old tyres, the burning of discarded electronics, and dust from construction sites and unpaved roads, especially in the dry season months. The PM_{10} and $PM_{2.5}$ data available for metropolitan areas in whole North-West geopolitical zone of Nigeria is for Kano Metropolis, which make Katsina data the Second as Airborne Particulate Matter is classified as a Group 1 carcinogen by the World Health Organization. as Particulates are the most harmful form of air pollution because of their ability to penetrate deep into the lungs, blood streams, and brain, causing health problems such as heart attacks and respiratory disease, especially with the recent emergence of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) commonly known as COVID-19, which can cause premature death with an underlined noticed or unnoticed death (WHO, 2021).

In 2013, a research on 312,944 persons from nine European nations found that there was no such thing as a safe level of particulates, and that the lung cancer rate increased by 22% for every rise of 10 $\mu g/m^3$ in $PM_{10.}$ $PM_{2.5}$, on the other hand, was more dangerous, causing an 18% rise in lung cancer per 5 $\mu g/m^3$ due to its ability to penetrate deeper into the lungs (Hamra et al., 2014). A number of adverse health impacts have been associated with exposure to both $PM_{2.5}$ and PM_{10}. For $PM_{2.5}$, short-term exposures (up to 24-hours duration) have been associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms, and restricted activity days. These adverse health effects have been reported primarily in infants, children, and older adults with pre-existing heart or lung diseases. In addition, of all of the common air pollutants, $PM_{2.5}$ is associated with the greatest proportion of adverse health effects related to air pollution, both in the United States and world-wide based on the World Health Organization's Global Burden of Disease Project (Davidson *et al.*, 2005). The objective of this paper therefore is to investigate particulate matter ($PM_{2.5}$ and PM_{10}) concentrations in aerosols selected Locations in Katsina Metropolis, Katsina State, Nigeria.

MATERIALS AND METHODS

Study Area: The study areas with their GPS locations are presented in Table 1 and Figure 1. These sites were selected based on population density, Urbanization and Economic activities (Efe and Efe, 2008; Joseph *et al* 2023) as well as harmattan haze (Dimari *et al.*, 2008) at the locations are major contributors to $PM_{2.5}$ and PM_{10} concentrations.

Table 1. The Sites, Location, Addresses and GPS Coordinates of the Sample collection sites

Site	Location	Address	GPS Coordinates
KTN 001	Al-Qalam Round About.	Along Katsina - Dutsin-ma Rd, Katsina.	Latitude: N 12^0 56'30 Longitude: E 7^0 36'24
KTN 002	KSRC Round About.	IBB Way, Katsina – Kano Rd, Katsina.	Latitude: N 12^0 57'52 Longitude: E 7^0 37'28
KTN 003	Kofar Kaura Round About	IBB Way, Katsina – Kano Rd, Katsina	Latitude: N 12^0 58'2 Longitude: E 7^0 37'25
KTN 004	FMC Katsina.	Murtala Mohammed Way, Katsina.	Latitude: N 12^0 59'23 Longitude: E 7^0 35'4
KTN 005	Rafukka	Muhammad Dikko Rd, Katsina.	Latitude: N 13^0 0'18 Longitude: E 7^0 36'18

Sampling and Sample Collection: The samples were collected using *Air - O - Cell*® Aerosol Sampling Cassettes. To collect the samples, two levelled cassettes (1 for PM_{10} and 1 for $PM_{2.5}$) were hung for 30 minutes at each location at an interval of 12 hours (during the day and at night) and taken to the Centre for Renewable Energy and Research, Umaru Musa Yaradua University, Katsina for Energy Dispersive X-Ray Florescence (EDXRF). The Glass Slide within the cassette containing the PM and its elemental composition in the Aerosols is used for Energy Dispersive X-Ray Florescence (EDXRF).

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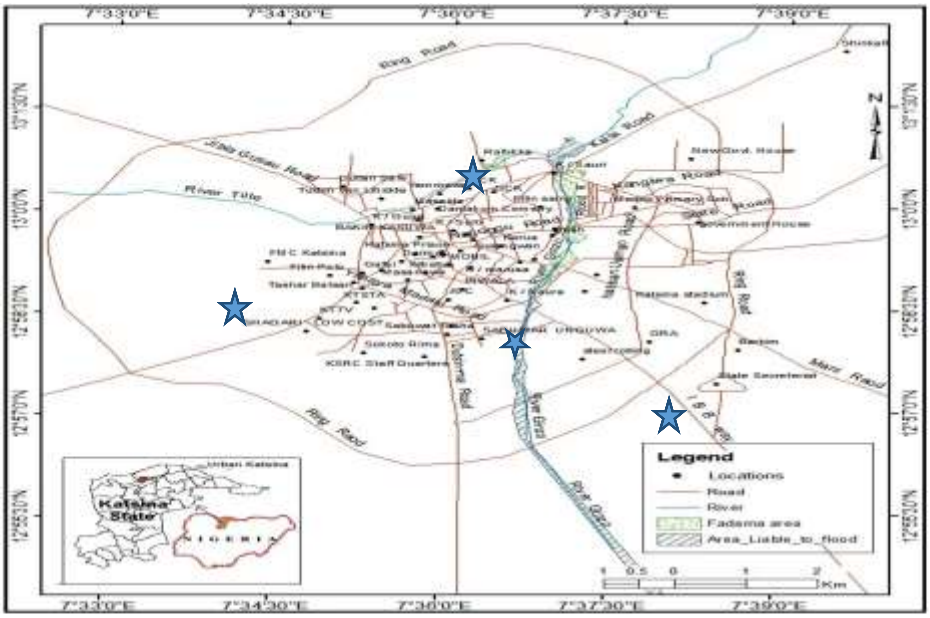

Fig 1. The Map of Katsina Metropolitan Area with proposed locations for Samples collection

Sample Preparation and Analysis: A total of Ten (10) Air - *O* - *Cell*® Aerosol Sampling Cassettes for $PM_{2.5}$ (1 at day, 1 at night per location) and Ten (10) for PM_{10} (1 at day, 1 at night per location) containing samples were prepared for EDXRF analysis. The samples are resealed and delivered to the laboratory for testing. The Cassettes were designed to be dismantled after sample collection without damaging the glass slides containing the Samples. The glass slides were loaded into the sample chamber of the spectrometer system.

Measurements were performed using Thermo-Scientific, ARL™ Quant'X EDXRF Analyzer. The Spectrometer with a mass of only 28 *kg* (2017 Model) produced in 2019, provides major, minor and trace Element Quantification across the broadest ranges of samples, including Bulk Solid, Powders, thin films and liquids.

The ARL™ Quant'X EDXRF spectrometer had an excitation system of 30 KV maximum, a minimum and maximum current of 1 μA and 1 *mA* respectively with a power rating of 9 *W*. It is fitted with thin film circle sample support (cup) with diameter of 63.5 *mm* where the powdered sample was placed. The primary beam filters were arranged in twelve positions for optimum function across the periodic table (Scientific, 2017).

RESULTS AND DISCUSSION

The Ranges and Mean Particulate Matter $PM_{2.5}$ and PM 10 in $\mu g/m^3$ of Aerosols in Katsina Metropolis were shown in Table 2 and Figure 2. In Katsina Metropolis, the average concentration of $PM_{2.5}$ and PM_{10} for locations KTN001 (41,161) $\mu g/m^3$, KTN002 (62,192) $\mu g/m^3$, KTN003 (42,187) $\mu g/m^3$, KTN004 (67,159) $\mu g/m^3$ and KTN005 (19,112) $\mu g/m^3$ which surpassed the WHO 24-hour guideline requirements for $PM_{2.5}$ and PM_{10}. It also stipulates that $PM_{2.5}$ must not exceed 10 $\mu g/m^3$ annual mean or 25 $\mu g/m^3$ 24-hour mean, and PM_{10} must not exceed 20 $\mu g/m^3$ annual mean or 50 $\mu g/m^3$ 24-hour mean, according to the guideline (WHO, 2021).

Table 2. Concentration of Particulate Matter $PM_{2.5}$ and PM_{10} in *μg/m³* of Aerosols in some locations in Katsina Metropolis.

SITE	Study Location	GPS Coordinates	Range $PM_{2.5}$(μg/m³)	Mean $PM_{2.5}$(μg/m³)	Range PM_{10}(μg/m³)	Mean PM_{10}(μg/m³)	Ratio $PM_{2.5}$/ PM_{10}
KTN 001	Al-Qalam Round About.	N 12⁰ 56'30, E 7⁰ 36'24	38 - 44	41	158 - 164	161	0.25
KTN 002	KSRC Round About.	N 12⁰ 57'52, E 7⁰ 37'28	41 - 83	62	175 -209	192	0.32
KTN 003	Kofar Kaura Round About	N 12⁰ 58'2, E 7⁰ 37'25	36 - 48	42	162 - 212	187	0.22
KTN 004	FMC Katsina.	N 12⁰ 59'23, E 7⁰ 35'4	47 - 87	67	148 - 170	159	0.42
KTN 005	Rafukka	N 13⁰ 0'18, E 7⁰ 36'18	14 - 24	19	82 - 142	112	0.17

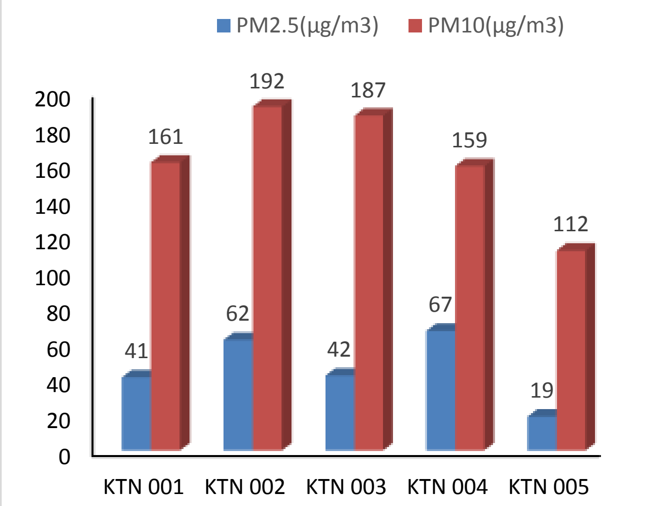

Fig 2. Concentration of Particulate Matter PM $_{2.5}$ and PM_{10} in μg/m³ of Aerosols in some locations in Katsina Metropolis

It also surpassed the National Ambient Air Quality Standard (NAAQS) 24-hour guideline limits for $PM_{2.5}$ and PM_{10}, which state that $PM_{2.5}$ should not exceed 15 μg/m³ annual mean or 35 μg/m³ 24-hour mean, and PM_{10} should not exceed 35μ g/m³ annual mean or 150 μg/m³ 24-hour mean (Chow and Watson, 1998). KTN 005 is the only exception (Rafukka), where the concentration is below the NAAQS 24 recommendations limit (19 μg/m³, 112 g/m³). The average $PM_{2.5}$ concentration ranged from 19 to 67 μg/m³, while the average PM_{10} concentration ranged from 112 to 192 μg/m³, indicating that about 80% of particulate matter loads in Katsina Metropolis exceeded both the WHO (25 μg/m³, 50 μg/m³) and NAAQS (35 μg/m³, 150 μg/m³) 24-hour guideline criteria limits for $PM_{2.5}$ and PM_{10}. The $PM_{2.5}/PM_{10}$ ratios for the selected study locations (table 3) are lower than the WHO guideline (0.5-0.8), implying that Katsina Metropolitan Area aerosols are mostly composed of coarse particles rather than fine particles.

Table 3. Concentration Levels of Particulate Matter in some Selected Nigerian Cities, some Global Cities, WHO and NAAQS 24-hour limit guideline criteria for $PM_{2.5}$ and PM_{10}.

Study Location	$PM_{2.5}$		PM_{10}		Ratio
	Range (μg/m³)	Mean (μg/m³)	Range (μg/m³)	Mean (μg/m³)	$PM_{2.5}/PM_{10}$
Aba	30 – 63.	46.9	190 - 416	302.58	0.16
Abuja	7 - 36	21.5	27 - 86	56.5	0.38
Calabar	8 - 11	9.7	26 - 54	39.9	0.24
Kano	41 - 85	63	22 - 343	340	0.19
Maiduguri	10 - 23	17	61 - 757	246	0.069
Ile -Ife	98 - 200	148.19	168 - 450	308.6	0.48
Katsina Metro	14 - 83	46.2	82 - 212	162.2	0.28
WHO 24 hrs guidelines		25		50	0.5 – 0.8
NAAQS 24 hrs guidelines		35		150	
Cairo, Egypt		86.24		184.15	0.47
Edemli, Turkey		9.70		36.4	0.27
ATHENS, GREECE		40.20		75.5	0.53

Table 3 above showed the comparison of concentration levels of Particulate Matter $PM_{2.5}$ and PM_{10} for Katsina Metropolitan Area and some Selected Nigerian Cities, some Global Cities, WHO and NAAQS 24-hour limit guideline criteria for $PM_{2.5}$ and PM_{10}. Katsina metropolitan area recorded a range of (14 – 83) μg/m^3 with a mean of 47.2 μg/m^3 for $PM_{2.5}$ and a range of (82 – 212) μg/m^3 with a mean of 162.2 μg/m^3 for PM_{10}.which showed that the particulate matter loads in Katsina Metropolis exceeded both the WHO (25 μg/m^3, 50 μg/m^3) and NAAQS (35 μg/m^3, 150 μg/m^3) 24-hour guideline criteria limits for $PM_{2.5}$ and PM_{10}. Also, the particulate matter loads in Katsina Metropolis exceeded both the WHO (25 μg/m^3, 50 μg/m^3) and NAAQS (35 μg/m^3, 150 μg/m^3) 24-hour guideline criteria limits for $PM_{2.5}$ and PM_{10} with the exception of KTN005 (Rafukka), where the concentration is below the NAAQS 24-hour recommendations limit (19 μg/m^3, 112 g/m^3).

These findings were inconsistent with the findings of an ambient air study conducted in Maiduguri, Borno State, Nigeria, between September and October 2009 as part of a countrywide screening operation on particulate matter loading in Nigeria. The average $PM_{2.5}$ (17 g/m^3) concentration was lower than the equivalent WHO and NAAQS 24-hr recommendation values for $PM_{2.5}$ in ambient air, whereas the average PM_{10} concentration (246 g/m^3) was much higher than the corresponding WHO and NAAQS 24-hour guideline values for PM_{10} in ambient (Obioh et al., 2013). The finding is also consistent with high PM_{10} values have been recorded in the North western city of Kano (340 μg/m^3), and (63μg/m^3) for $PM_{2.5}$ which is greater than both the WHO and the NAAQS 24-hr guideline criteria for $PM_{2.5}$ and PM_{10} (Efe, 2008). The findings agreed with a research on review on Particulate Matter and elemental composition in Nigerian Aerosols from 1985 to 2015, which revealed that $PM_{2.5}$ concentration ranged from 5-248 μg/m3, while PM_{10} concentration ranged from 18-926 μg/m^3, revealing that about 50% of the particulate matter loads in Nigeria exceeded both the WHO (25 μg /m^3, 50 μg/m^3) and NAAQS (35 μg/m^3, 150 μg/m^3) guideline limits for $PM_{2.5}$ and PM_{10} respectively. $PM_{2.5}/PM_{10}$ ratios for the selected studies fall below the WHO guideline (0.5-0.8), suggesting that Nigerian aerosols are mainly made up of coarse, rather than fine particles (Offor et al., 2016). Our findings completely disagrees with the findings of a research on Trace metal solid state speciation in aerosols of the northern Levantine Basin, East Mediterranean which revealed the mean $PM_{2.5}$ and PM_{10} concentration for Erdemli, Turkey as 9.7 μg/m^3 and 36.4 μg/m^3 respectively (Kocak et al., 2017). Another research finding on Measurements of PM_{10} and $PM_{2.5}$ particle concentrations in Athens, Greece also disagree with the findings revealing the mean $PM_{2.5}$ and PM_{10} concentration for Athens, Greece as 22.2 μg/m^3 and 36.4 μg/m^3 respectively, which both are within the WHO and NAAQS 24-hour guideline criteria limits for $PM_{2.5}$ and PM_{10} (Chaloulakou *et al*, 2006).

Higher limits of Particulate matter in Katsina metropolis can be as result of urbanization and other economic activities without due regulation and the dust particles from the Sahara blowing North to South. These activities include indiscriminate incineration of Hospital and domestic waste, Electronic products, burning of used tyres, traffic congestion etc. within Public, Residential and Official Areas in the Metropolitan Area.

Conclusion: The study has presented the ranges and mean Particulate Matter ($PM_{2.5}$ and PM_{10}) in μg/m^3 of Aerosols in Katsina Metropolis. The result of our findings showed that the PM of the study areas are high. The activities that causes raise in PM concentration such as indiscriminate incineration of Hospital and domestic waste, electronic products, traffic congestion, etc. be address by relevant authorities immediately. Studies on Particulate matter should be encourage as data on PM is very scanty especially in North West Nigeria.

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