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FINE PARTICULATE MATTER-BASED AIR QUALITY INDEX: A CASE STUDY

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ABSTRACT

The impact of air pollution on human health can be communicated through the application of air quality index (AQI). This has been underutilized in the developing countries due to inadequate technology. In this study, ambient fine particulate matter ($PM_{2.5}$)-AQI in selected industrial areas in Ogun State, Nigeria was evaluated during weekends of wet season. $PM_{2.5}$ samples were collected on Teflon filters using Environtech gravimetric sampler. AQIs were further computed following the United States Environmental Protection Agency (US EPA) formulae. The result showed that for the major part of the wet season, the weekend air quality was categorized as "unhealthy" in all the industrial sites. An indication of possible adverse health concerns especially for the sensitive group. In addition, gradations of 0 to 50, representing the good AQI category was not observed. Therefore, synergy from Engineers, Scientist and Policy makers is required towards the availability of sensitive and low cost instruments. A permanent network of air quality monitoring stations and reporting system for on-time information on air pollutants should be established by the government. Also, a community project on greenbelts development programme is strongly recommended.

Key words: Air quality index, Industrial area, Low cost instrument, Nigeria $PM_{2.5}$ pollution.

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1. INTRODUCTION

Unpolluted air is an important asset to living beings and the environment [1-2]. Air pollution occurs due to the introduction of chemicals, biological materials and particulate matter into the atmosphere in a concentration that is toxic to humans, other living organisms and the environment [3-4]. Amongst these emitted pollutants, fine particulate matter ($PM_{2.5}$) has been identified by several researchers as a significant health indicator of air quality [5-6].

$PM_{2.5}$ is a microscopic particle that is often responsible for causing air pollution-related health issues [7-8]. Increasing trend in fine particulate matter has been observed for Nigeria, as shown from the little green data book of 2015 and 2017. Comparing both years, World Health Organization (WHO) report indicates that 94 and 100% respectively of the population is exposed to $PM_{2.5}$ air pollution levels which exceeds the National Ambient Air Quality Standards (NAAQS) guidelines of 12 μg/m^3 on annual average and 35 μg/m^3 on daily average [9-10]. In addition, air pollution damage costs have increased from about 1 to 1.5% post of Gross National Income [11-12]. According to United Nations Environment Programme estimations, about 600,000 deaths recorded yearly across the world are associated with air pollution [13].

Measuring $PM_{2.5}$ concentrations and apportioning its sources is fundamental in formulating policies geared toward emission control. Hence, its wide application in setting air quality guidelines worldwide [14]. In developed countries, on-ground monitoring of $PM_{2.5}$ air quality is continuously evaluated due to ease of access to sophisticated equipment, sustained funding, and regulatory support, which is a major drawback in the developing countries [15-16]. There is a global need of availability of sensitive and low cost instruments to aid quick control of critical emissions [17-18]. A challenging gap for Engineers, Scientist and Policy makers to fill.

In the quest to ascertain the state of the air we breathe, air quality index (AQI) or air pollution index (API) has found prominence. AQI is a colour-coded tool for notifying the public of the local level of ambient air pollution, the potential health risk it would impose and ways to reduce their daily exposure to pollution [1, 19-20]. AQI values are obtained by evaluating measured pollutant concentrations into index values. It has been computed for the criteria pollutants including carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) lead (Pb) and particulate matter ($PM_{2.5}$) [20-21].

Some of the Countries using AQI or API generated data to communicate air quality and inform policy at local, national and regional levels includes, the United Kingdom (UK), United States of America (USA), Finland, China, Thailand, Canada, France, Mexico, Australia etc. [21]. These data have been useful in making decisions on outdoor activities particularly for the vulnerable groups such as children, the elderly, and those with existing cardiovascular and respiratory diseases [2-3].

In Ogun State, industries and transportation are major contributors to air pollution. Gaseous emissions from chimneys, stacks, petrol/diesel-powered backup generators, open burning of solid waste, improper disposal of sewage water, gales of dust particles from blasting of limestone rocks are conspicuously evident in industrialized areas [7, 22, 23]. In addition, emission from transport related sources is exacerbated by traffic congestion, inefficient vehicles, unpaved road networks, and incomplete combustion of fossil fuel [24].

Few studies have been conducted on the quality of air via AQI in Nigeria at different times and locations including, Abuja [2]; Lagos state [8]; Ogun state [1]; Imo state [3]; River state [25-26] etc. In the absence of continuous air pollution monitoring system in Nigeria, the present study investigates the state of fine particulate matter air quality in industrial areas in Ogun state, by generating a fine particulate matter air quality spatial map ($PM_{2.5}$–AQI spatial map).

2. MATERIALS AND METHODS

2.1. Sample Collection

Twenty-eight (28) $PM_{2.5}$ samples were collected during the weekends of wet season (July, September, October) on Teflon filters using Environtech Gravimetric Sampler (Model SLE-FPS105). The filters were equilibrated in a desiccator for 48 hours to eliminate the effect of humidity and weighed thrice before and after sampling using a microbalance (Mettler Toledo Me 204). Blank filters were collected to reduce gravimetric bias due to filter handling [27]. After sampling, the $PM_{2.5}$ filter papers were removed with forceps, stored in a petri dish, conditioned, weighed, and preserved in the refrigerator at 4^oC to prevent thermal degradation and evaporation of volatile components prior to further analysis. Field and laboratory blank samples were collected in order to reduce gravimetric bias resulting from filter handling, before, during and after sampling.

2.2. Study Area

The study area for this research was Ogun State, one of the most industrialized States in Nigeria with a population of about 3,751,140 (28-29). It shares a common boundary with metropolitan Lagos, which is known as Africa's fastest growing city. The study location comprised of three industrial areas and a background: Ota Industrial Estate (OTE), Ewekoro Community (EWC), Agbara Industrial Estate (AGE) and one background location which was Covenant University Farm (CUF). Geographical locations were geo-referenced with a handheld Garmin-GPSMAP 76S equipment. The coordinates and major activities in these locations can be seen on Table 1.

Table 1 Description of sampling site and major local emission sources

Location	Site classification	Coordinates	Study site activities
Ota Industrial Estate	OA	31N 0522050 UTM 0736371	Recycling of metal scraps, schools, churches, residential houses, manufacturing of plastics, zinc, chemical products, detergent, steel mill, vehicular traffic, commercial shops, etc.
	OB	31N 0522403 UTM 0737629	
	OC	31N 0521866 UTM 0738087	
Ewekoro Commnunity	EA	31N 0523383 UTM 0763957	Cement and paint manufacturing, recycling of scraps, constructions, railway line, schools, tipper park, farming, vehicular traffic.
	EB	31N 0523068 UTM 0763651	
	EC	31N 0522334 UTM 0762491	
Agbara Industrial Estate	AA	31N 0509888 UTM 0719892	Food, drugs, beverage industries, gas plants, wood mills, hospitals, schools, churches, vehicular traffic, residential houses, constructions, solid waste, mechanic-workshops.
	AB	31N 0508845 UTM 0719916	
	AC	31N 0508802 UTM 0720895	
Covenant University Farm, Ota	CA	31N 0517520 UTM 0736588	Farming, welding of farm tools and a farm house.
	CB	31N 0517526 UTM 0736567	
	CC	31N 0517549 UTM 0736609	

2.2. Determination of $PM_{2.5}$ Mass Concentrations and Air Quality Index (AQI)

$PM_{2.5}$ mass concentrations were determined by gravimetric method of analysis according to California Environmental Protection Agency (CEPA) [27]. AQI was calculated using $PM_{2.5}$ mass concentration data, the two breakpoints which contain the concentration from the revised break- points table for fine particle pollutant (Table 1.0) and a standard AQI formula developed by the US EPA [19-20, 30] as shown in equation (1):

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}\left(C_P - BP_{Lo}\right) + I_{Lo} \tag{1}$$

where Ip is the index for pollutant p; Cp is the rounded concentration of pollutant p; BPHi is the breakpoint that is greater than or equal to Cp; BPLo is the breakpoint that is less than or equal to Cp; IHi is the AQI value corresponding to BPHi and ILo is the AQI value corresponding to BPLo.

Table 2 Revised AQI breakpoints, colour and health implications.

$PM_{2.5}$ (μg/m^3, 24-hour average)	Index Values	AQI Category	Colour	Implications
0.0 – 12.0	0 – 50	Good	Green	Satisfactory
12.1 – 35.4	51 – 100	Moderate	Yellow	Acceptable
35.5 – 55.4	101 –150	Unhealthy for Sensitive Groups	Orange	GENERAL public may not be affected, but could affect the vulnerable group
55.5 –150.4	151–200	Unhealthy	Red	EVERYONE may begin to experience some adverse health effects
150.5 –250.4	201– 300	Very Unhealthy	Purple	EVERYONE may experience adverse health effects
250.5 –350.4	301– 400	Hazardous	Maroon	TRIGGERS health warning of emergency conditions
350.5 – 500	401– 500	Hazardous		

3. RESULTS AND DISCUSSION

3.1. Spatial map generated from $PM_{2.5}$- air quality index

AQI is classified into six levels of health concern which ranged from good to hazardous as shown in Table 1.0. They are: good (0–50), moderate (51–100*), unhealthy for sensitive groups (101–150), unhealthy (151–200), very unhealthy (201–300) and hazardous (301–500). A $PM_{2.5}$ level above 500 is known as beyond index. An AQI value of 100 as identified with the asterisk symbol, generally corresponds to the NAAQS set by the environmental protection agency to protect the public from air pollution. AQI value above 100 suggests the pollutant concentration exceeds the NAAQS, and is considered unhealthy at first for the vulnerable category, then for everyone as AQI values increases [19-20, 32]. Fig 1.0 shows a $PM_{2.5}$–AQI spatial map generated during the wet season weekends. Nigeria belongs to the tropical climate and has two distinct seasons, namely wet and dry seasons. During this period, the weather was characterized by moderate to heavy rainfall.

The result indicates that for the major part of the wet season, the weekend air quality was categorized as “unhealthy” in all the industrial sites (OTE, EWK and AGB). Wet season exhibits high relative humidity as such should translate to a significant decrease in the concentration of accumulated particles due to its ability to wash out atmospheric particulates from the atmosphere [32, 33].

On comparing the status of air in the industrial sites with the background site (CUF) a remarkable difference in the category of “moderate” to “unhealthy for sensitive group” at about 60% occurrence was observed. Even though the air in CUF was of improved quality as compared to the industrial locations, there is strong possibility of pollutants transport from OTE, which is the closest to CUF.

The state of air quality in the industrial location can be explained from this underlying fact: OTE and AGE representing Ota and Agbara industrial/residential estate have the largest concentration of functioning industries in Ado-Odo/Ota local government area. Being a mixed community, it is majorly influenced by industrial activities such as scrap recycling, production of chemicals, pharmaceuticals, food and beverages, plastics, woods, metals and steel as well as other activities: traffic congestion, fugitive dust from unpaved roads and residential heating using wood and stove amongst others. The pollutants emitted from chimney, stacks, and open burning of solid waste with little or no effective pollution emission control pose a threat to human health and the environment [7]. This result compares favourably with previous results obtained by applying a modelled data on Ota industrial estate pollution loads [22] and Agbara industrial estates [34].

The “very unhealthy’ category shown in the spatial map for OTE, is in line with the common occurrence of thick black and whitish emission from chimney, along with noxious gases, fumes, smoke and dust, causing itching of the throat, coughing, and irritation of the eyes and nose at site OB and OA while site OC had continuous direct emission of thick black, and whitish fumes from chimneys of the surrounding industries.

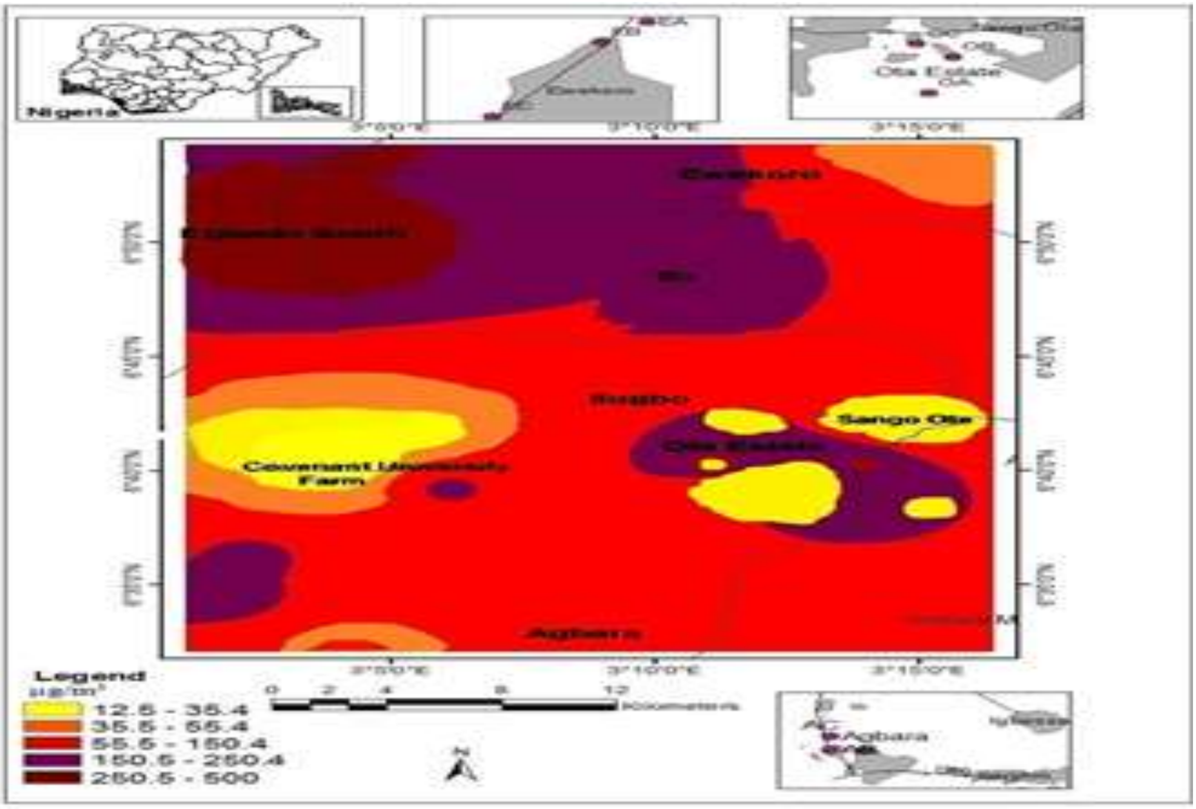

Figure 1 Spatial map of weekend PM $_{2.5}$-AQI in study area during wet season

Unhealthy air quality in AGE, can be attributed to a combination of particle emission from industries, buildings and roads construction, fugitive dust from unpaved roads, dust from the wood market, traffic congestion, residential heating using wood and stove and the frequent open burning of solid wastes along Atan/Agbara road. This result corroborate with poor air quality index results earlier reported for Lagos State, a nearby industrialized city hosting about 300 industries [4, 34]. corroborate with poor air quality index results earlier reported for Lagos State, a nearby industrialized city hosting about 300 industries [4, 34]. Therefore, Lagos state contribution to the $PM_{2.5}$ -AQI results observed in this study cannot be overruled.

Furthermore, the “unhealthy” air quality in Ewekoro (EWC) can be attributed to particle pollution caused by different industries, limestone quarrying, loading and unloading of cement, fossil fuel and heavy metals emission from heavy vehicles, woodstoves, power plants, unpaved roads, open burning of solid waste and tyres, reaction of gaseous pollutants such as sulphur dioxide (SO_2) and nitrogen oxides (NO and NO_2, referred together as NOx) [1, 35]. The adverse effect of these particle pollution has resulted in frequently reported health conditions including, coughing, wheezing, and asthma, itchy skin, eye problem, stomach ache, pneumonia, and respiratory tract diseases amongst others [36].

Hence, the poor air quality in this work can also be attributed to particle emission from a combination of industrial, commercial, domestic sources as well as transport of pollutants from Lagos State following the close proximity of the study areas to Lagos State. Overall, most weekend AQI values were above 100, signifying poor air quality. Only 11% of the wet season weekend air quality reflected the moderate category (51 – 100*). Hence, there is a strong tendency of possible adverse health concerns, especially for the sensitive group. Based on the foregoing its pertinent to observed continuous on-ground air quality monitoring. Following the need to develop a low-cost sensor (LCSs) capable of tracking and identifying pollution hotspots [37], harmonisation of a wide range of technology is required to make it a suitable substitute for reference instrument.

Furthermore, necessary measures should be adopted by governments to curb emitted pollutants such as setting up efficient public transport, mass transit, cleaners fuels, safe waste disposal and strict enforcement of emission control [13,30]. In the interim, affected communities can contribute to cleaner environment through greener approach projects such as screening trees with high dust accumulation potential, tolerant and good performers status, for greenbelts development programme [38-40].

4. CONCLUSIONS

The generated spatial map for wet season weekend duration with respect to $PM_{2.5}$–AQIs, indicates possible adverse health concerns due to the above 100 set limit signal across the study locations. There is a dire need for Engineers, Scientist and Policy makers to focus on ensuring availability of sensitive and low cost instruments to aid quick control of critical emissions.

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