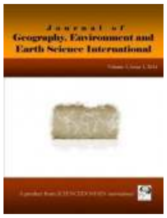

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Measurement of Total Suspended Particulate Matter (TSP) in an Urban Environment: Yenagoa and Its Environs

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Authors' contributions

This work was carried out in collaboration between all authors. Author AED designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Authors IAK and BAE managed the analysis of the study. Authors AN and UAS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study reports the ambient concentrations of total suspended particulate matter (TSP: both respirable and non-respirable) measured in Yenagoa and its environs as means of determining the distribution of particulate matter to assess the ambient air quality of a fast growing urban town in Southern Nigeria. Particulate matter was collected at five stations (Berger junction, Onopa government house, Tombia Roundabout, Gbaran Ubie and Ogbogoro Village), using a high volume portable SKC air check MTX Sidekick air sampler (Model: 224-52MTX). The mean TSP Matter measured at each of the five locations are 1189.857 μgm^{-3}, 662.4286 μgm^{-3}, 1406.4286 μgm^{-3}, 1623 μgm^{-3}, and 757 μgm^{-3} respectively. The data obtained were subjected to a set of multivariate

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statistical analysis. The results showed that the TSP in all stations correlated well, except between Gbaran Ubie and Ogbogoro Village due to marked differences in pollutant sources. The calculated Toxicity Potential shows values greater than unity at all the stations.

Keywords: Air pollution; Particulate Matter (PM); Toxicity Potential (TP); gas flaring; Total Suspended Particulate Matter (TSP).

1. INTRODUCTION

Particulate matter (PM) is a complex mixture of suspended solid and liquid particles classified into primary (particles emitted directly from source) and secondary (particles formed through atmospheric reactions with gases) particles. TSPs are introduced into the atmosphere from a variety of natural and anthropogenic sources, although the latter are predominant in the urban and industrial areas [1]. Natural sources like dust, generally contributes particle matter (aerosols) of sizes >10 μm in diameter, while anthropogenic sources contributes <10 μm (classified under PM_{10}) sized particulate matters [2]. Fine particles consist of PM with diameter between 0.1 and 2.5 μm. they account for the majority of the mass of the suspended particles and deposit slowly leading to a long atmospheric lifetime of 5-10 days. These particles may penetrate deep inside the airways and are more strongly linked with adverse health effects [3].

Therefore, understanding the composition of particulate matter is crucial especially to research that evaluates health risk factors. Yenagoa is the capital of Bayelsa State, one of the newly created states located in the low lying coastal area of Niger Delta region. Besides activities from structural development and increasing vehicular movement, intensive production of oil and gas flaring is highly visible in the state. Generally, the Niger Delta is faced with a range of environmental problems including agricultural land degradation, renewable resources degradation, water contamination, solid waste, and air pollution [4-8]. Vehicular emission sources have been reported in previous studies as one of the largest sources of TSP in ambient air [9-11]. TSP is the most evident air pollutant in the Nigeria urban and rural ambient environment. [12]. The choice of TSP as an index of ambient air pollution is obvious. Levels as high as 40, 000 μgm^{-3} have been recorded in some industrial sites, while up to 1033 μgm^{-3} were reported for ambient air [13]. Earlier reports of TSP, their elemental concentrations within and around sites, road side dust and its effect on soil, vegetation and crops [14] have been written. The average load of TSP in Warri, an industrial city close to Yenagoa was 1332.75 μgm^{-3} [15].

Airborne particulate related trace metals have been linked with acute adverse health effects, including respiratory diseases, lung cancer, heart diseases, and damage to other organs. Mortality and morbidity associated with air pollution are primarily due to toxic effects of PM [16-18].

Despite the literature on air pollution in Niger Delta region, there is a paucity of literature related to Bayelsa State, where oil production started in 1956. The aim of this study, therefore, is primarily to determine the levels of Particulate Matter distribution in Yenagoa and its environs identify the major factors responsible, and ascertain whether the limits set by national and international agencies have been exceeded.

2. DESCRIPTION OF STUDY AREA

Yenagoa is a Local Government Area (LGA) in Bayelsa State, Nigeria. It lies between 4°55′29″N and 4.92472°N latitude and 6°15′51″ E and 6.26417°E longitude (Fig. 1). It has an average elevation of 9 m. It is the capital of Bayelsa State and Yenagoa LGA. The city is located on the banks of Ekole Creeks and Nun River, the latter being one of the major river courses making up the Niger Delta's River. Yenagoa is the northernmost city of the state's significant population center. It shares its boundaries with Rivers in the South, Delta in the West, and Imo in the Eastern and Northern part.

The study area is Yenagoa and its environs. It is located in the low lying coastal area of Niger Delta. The vegetation is that of a typical wetland, with two seasons (wet and dry). The temperature throughout the year ranges between 28.6°C to 37.5°C. The dry season lasts from November to March and the rainy season from April to October. The predominant occupations are fishing and farming, but carried out on a small scale. The relative humidity ranges between 61 to 90%. The total area of Yenagoa is 706 km^2, with a total population of 353,344 [19].

2.1 Sampling Sites

The following stations (Berger junction (AQBJ), Onopa government house (AQON), Tombia Roundabout (AQTR), Gbaran Ubie (AQGU) and Ogbogoro Village (AQOV)) were selected for monitoring. The coordinates of the sampling sites and the predominant activities occurring at the sites are shown in Table 1. Fig. 1 is the map of the study area.

3. METHODOLOGY

Particulate matter samples were collected daily from 8 am to 4 pm for seven months, using a SKC air check MTX Sidekick sampling pump, 224-52MTX Model by filtration through Whatman membrane filters of 25 mm, with pore size of 3.0 μm [3,20]. Both wet season (July, August, September, and October) and dry season (November, December, and January) were covered. The high volume sampler operates at a flow rate of 2.2 L $min^{-1.}$ A total of 1056 L 8 h^{-1} air was collected on each occasion. This sampling unit consists of a filter holder manifold connected to the sampling pump by a Teflon tube. Airborne particulate matter was collected on Whatman filter paper from five different sampling stations (Berger junction (AQBJ), Onopa government house (AQON), Tombia Roundabout (AQTR), Gbaran Ubie (AQGU) and Ogbogoro Village (AQOV)), local activities of the stations are shown in Table 1. The sampler was installed on top of a building approximately 4.0-6.0 m high above the ground level and separate other buildings.

3.1 Weighing of Filter Papers

Filter papers were equilibrated in a desiccator for 24 hours and weighed before and after sampling. An AE200 weighing balance was used. Each filter was weighed three times to obtain a constant and accurate weight before recording. Blank filter papers were also kept in a desiccator for 24 hours and weighed three times to obtain constant weight, but were not exposed to air. They were kept in paper envelopes (for correction purposes). All filter handling was done using vinyl gloves to avoid contamination.

Table 1. Station, locations, coordinates, and local activities

S/N	Sampling location	Location code	Coordinates	Activities	Distances between location (Ref: AQOV) (Km)
1	Berger Roundabout	AQBJ	N4^{0}53'22.2" E6^{0}18'40.1"	Pulverization of granite, road construction, vehicular movement, road traffic.	3.67
2	Onopa(Govt House)	AQON	N4^{0}56'23.2" E6^{0}16'44.1"	Vehicular movement, Road traffic, road construction, residential activities.	4.65
3	Tombia Roundabout	AQTR	N5^{0}00'08.6" E6^{0}15'41.2"	High vehicular movement, road traffic, commercial activities, open dump site, residential activities, abattoir, burning of animal parts.	9.81
4	Gbaran Ubie	AQGU	N4^{0}48'22.4" E5^{0}54'40.0"	Gas flaring, Vehicular movement, residential activities.	13.58
5	Ogbogoro Village	AQOV	N4^{0}54'08.6" E6^{0}14'50.8"	Road construction, few vehicular movements, low residential activities.	0

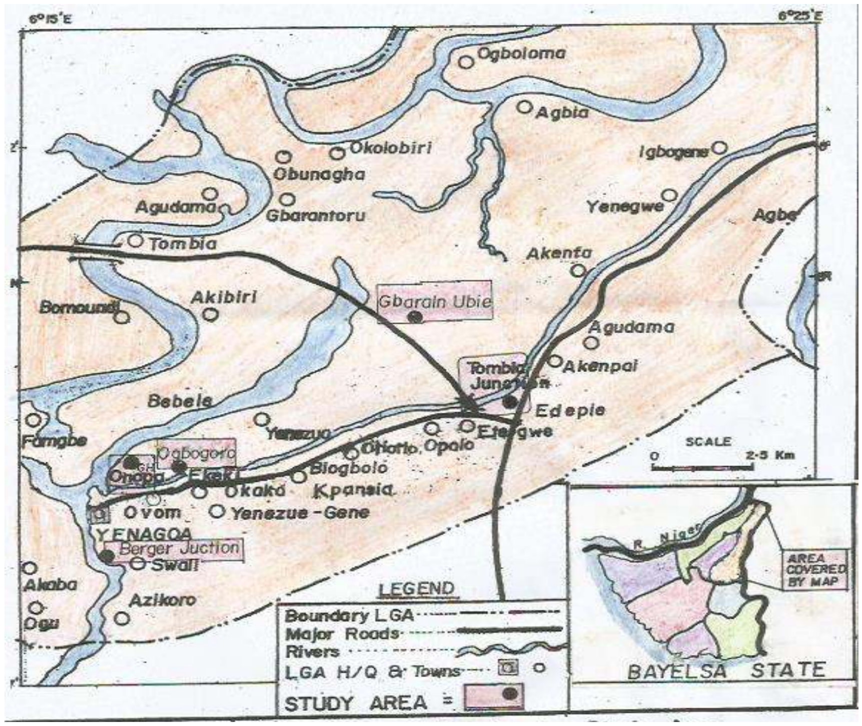

Fig. 1. Map of central Yenagoa displaying the sampling stations

3.2 Collection of Samples

The particulate matter was obtained by pumping air through the filter paper, sampling was performed on regular 8 hours basis (excluding Sundays), starting at 08:00 h, during July 2013–January 2014. A total of 147 total suspended particulate (TSP) samples were collected [20,21]. After sampling, the loaded filter paper was again put in a desiccator and reweighed to determine the final weight. The concentration of the TSP in the air was determined from the difference in weight of the filter paper after and before sampling, the duration of sampling and the flow rate [20,21] shown by Equation 1.

$$\frac{\left[Final\ weight\ (W_f)_g - Initial\ weight\ (W_i)_g\right] X10^6}{Volume(V)} \qquad (1)$$

W_f = Weight of filter paper after sampling in grams

W_i = Weight of filter paper before sampling in grams

Volume = Flow rate (m^3/ min) X sampling period (min)

10^6 = conversion from grams to micrograms.

Due to the daily exposure to PM, the probability of its effect on human health exists therefore, Toxicity Potentials (TP) were calculated.

4. RESULTS AND DISCUSSION

The mean TSP measured in each of the five locations; AQBJ, AQON, AQTR, AQGU and AQOV are; 1189.857 μgm^{-3}, 662.4286 μgm^{-3}, 1406.4286 μgm^{-3}, 1623 μgm^{-3}, and 757 μgm^{-3} respectively, on the average 1,127.46 μgm^{-3}. This exceeded the WHO and the Nigeria Ambient Air Quality Standard of 50 μgm^{-3} [22] and 250 μgm^{-3} [23] respectively, (Fig. 2). Data obtained were subjected to Pearson's correlation (Table 2) and the various locations correlated well, processed data were performed using IBM SPSS statistics version 21 statistical software. However, Gbaran Ubie and Ogbogoro village showed a slight variation and this is connected to the marked differences in the nature of local pollutant activities, and the distance of each city from each other.

The values obtained in this study were compared with the international guidelines by WHO and USEPA, as well as with the data from other sites around the world as shown in Table 3. The TSP levels measured during this study were found to be significantly higher than WHO, and USEPA standard values of 80 μgm^{-3} and 60 μgm^{-3} respectively [22,24]. A number of health related problems may thus be associated with elevated TSP in the atmosphere. Average TSP levels in the atmosphere of Yenagoa were significantly higher than those reported from Brisbane [25], Tokyo [26], Benin City [27] and Santa Cruz [28], Lagos [10] while, the present levels were lower than those reported from Kenya [29] Warri [15], Benin City [30] This shows that natural and anthropogenic sources are likely responsible for the measured high levels, including increasing volume of high vehicular flow in Yenagoa and its environs, flare gases from well-heads, and road construction activities. This is in support of studies carried out by [15,30,31].

The study shows that there are seasonal variations in the concentration of TSP in the study areas. During the rainy season it was observed that the TSP concentration levels were lower during the wet season than their levels during the dry season. This could be as a result of the mode of deposition of particulate matter in both seasons. During the rainy season, particulate matter could easily be precipitated from the atmosphere, thus reducing its concentration in the atmosphere during sampling (Fig. 2). The level of TSP was highest at Tombia Roundabout during the dry season, while during the rainy season it was highest at Gbaran Ubie. Onopa and Ogbogoro Village had the lowest levels of TSP in both seasons. This variation in the concentration of TSP is connected to the local activities carried out at the stations, for example Tombia Roundabout has high vehicular movement, road traffic, open dump, while at Ogbogoro Village there is few vehicular movement, low residential activities. Therefore the level of TSP is high at Tombia Roundabout compared to Ogbogoro Village.

TP values were calculated using Equation 2 below [32].

$$TP = \frac{\text{The mass concentration of the total suspended particulate}}{\text{The statutory limit sets for ambient particulate matter concentration}(250\mu gm^{-3})} \quad (2)$$

TP values exceeding unity gives cause for concern. The TP values obtained are as stated in Table 4.

Table 2. Correlation matrix of Total Suspended Particulate Matter (TSPM) of study areas

Site code	AQBJ	AQON	AQTR	AQGU	AQOV
AQBJ	1.000				
AQON	**0.861**	1.000			
AQTR	**0.663**	**0.642**	1.000		
AQGU	**0.503**	**0.686**	**0.557**	1.000	
AQOV	**0.771**	**0.787**	**0.671**	0.251	1.000

Table 3. TSP obtained from cities in Nigeria and other countries of the world

Cities	TSP($\mu g/m^3$)	Source
Yenagoa	1,127.46	This study
Benin-City	1,666.56	Ediagbonya et al. (2013) [30]
Benin City	675	Ukpebor et al. (2006) [27]
Warri	1,332.8	Okuo and Ndiokwere (2006) [15]
Santa Cruz, Brazil	87	Quiterio et al. (2004a) [28]
Lagos	800	Baumbach et al. (1995) [10]
Ogbomoso	1,929	Sonibare et al. (2005) [32]
Jos	911	Simonelt et al. (1988) [33]
Kenya	24,369	Karue et al. (1992) [29]
Tokyo/Japan	28	Tanaka et al. (2000) [26]
Brisbane, Australia	26.6	Chan et al. (1997) [25]
Mexico City	272	Sato et al. (1995)[34]

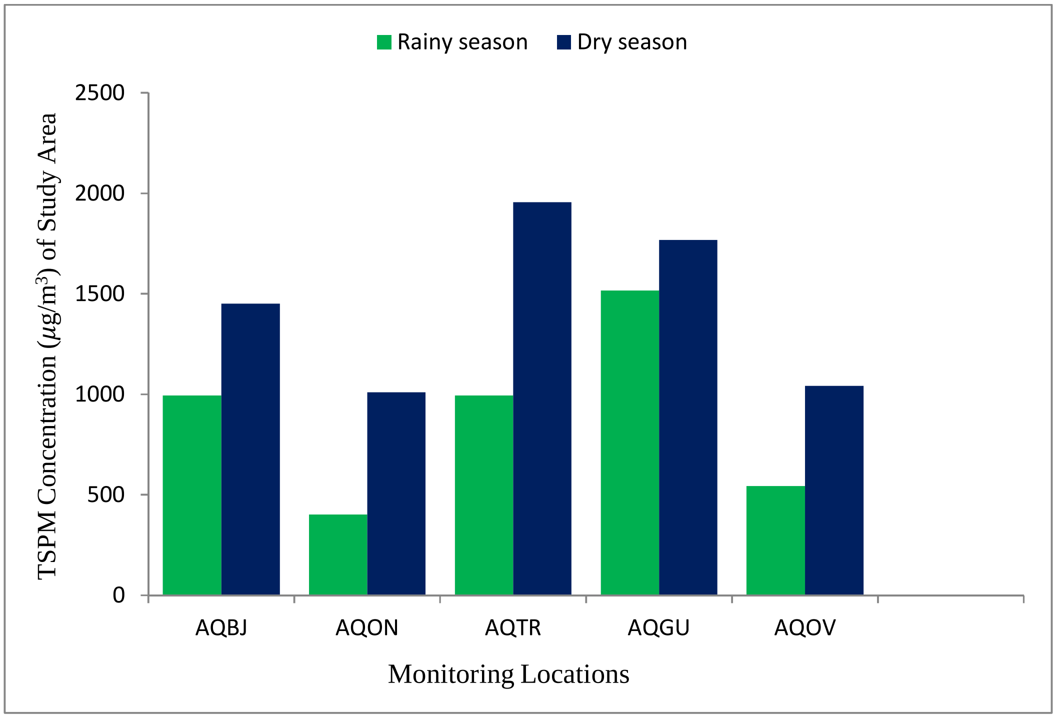

Fig. 2. Average concentration of TSP (μg/m^3) of study area

Table 4. Toxicity potential of TSPM concentration in Yenagoa and its environs

S/n	Stations	Toxicity potential
1	AQBJ	4.759
2	AQON	2.649
3	AQTR	5.625
4	AQGU	6.492
5	AQOV	3.028

However, in all the locations the toxicity potentials were greater than one and the toxicity potentials fall within the range of 2.64-6.50. The highest toxicity potential was recorded at Gbaran Ubie, which is not far from a gas flaring station, and construction sites, while Onopa had the lowest values.

5. CONCLUSION AND RECOMMENDATION

The results of this study revealed elevated 8 hour TSP concentrations which were significantly higher than the regulatory agencies standard. The estimated TSP concentration were higher than most of the cities in the world. Correlation study shows anthropogenic contribution of the high level of TSP, this may be associated with adverse health effects on the people of the areas. Major Sources of high level of TSP in the study area are increasing volume of high vehicular flow, road construction, and flare gases from well-heads. It is therefore recommended that the high levels of TSP measured be mitigated by implementing measures to control the factors responsible for increase in TSP.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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