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Abstract: Human health is at risk when particulate matter levels reach a certain threshold, and determining these levels is crucial for mitigating environmental pollution. Since there is a lack of data in this field of study, it is anticipated that this work will provide stakeholders with data. On the basis of this supposition, an Airly sensor was used to assess the air quality at a location in Mafoluku, Lagos, Nigeria. Following the manufacturer's instructions, the installation was done at a height of 1.8 meters above the ground. Outdoor PM_1, $PM_{2.5}$, PM_{10}, PM ratios, toxicity potentials (T/P), climatic factors, and their correlations were measured during a two-month period. The findings indicate that the levels of PM_{10}, $PM_{2.5}$, and PM_1 were 36.12 µg/m³ (equivalent to 80.7% of the WHO annual limit), 34.83 µg/m³ (equivalent to 232.23% of the WHO annual limit), and 34.39 µg/m³ (no limit for the calculation), respectively. The corresponding average ratios were 0.98, 0.95, and 0.93. The majority of T/P values were greater than 1, which suggests that there are health risks to the area's most vulnerable residents. Winds from the southwestern desert influenced the air mass, and WHO limits are often exceeded. The study suggests stakeholders focus on problem reduction to mitigate air pollution risks.

Keywords: Airly sensor; WHO; specific threshold; particulate matter; human health

1. Introduction

A major threat to public health is ambient air pollution, of which particulate matter [1,2] is one of the air contaminants with the greatest proof of health effects. Of these, fine particulate matter (PM_{10}, $PM_{2.5}$, PM_1), which have aerodynamic diameters of less than 10, 2.5, and 1 micrometers, are the appropriate indicators for urban air quality [3] and have been identified risk factors for health. They breach the lung's defenses, enter the bloodstream, and compromise the blood-brain barrier, leading to neurological, cardiovascular, and respiratory disorders as well as early mortality [4–6].

Though their spatial coverage is typically constrained, data from ground monitors is favored for analysis globally. Many attempts have been made to measure $PM_{2.5}$ concentrations using alternative techniques, such as satellite-based imaging and atmospheric chemistry models, in order to get around this issue. These techniques, however, are meant to supplement surface ground-monitored data rather than completely replace it [7]. To fully utilize the advantages of each data source and provide more accurate estimates of $PM_{2.5}$ concentrations on a large scale, it is recommended to integrate data from satellite imaging, ground-based monitors, and other models [8]. Lagos has not yet been the subject of this kind of study.

A thorough analysis of the most recent research shows that ambient PM concentrations in Lagos and other places have produced a range of findings. Table 1 illustrates how the location, season, time period, and year of measurement all affect the PM concentrations. Satellite data was utilized in one article, although it wasn't calibrated using ground-level readings [9]. Other studies [10–15] gathered PM data using air samplers for brief periods of time, typically less than three months. The average yearly PM concentration in Lagos cannot be calculated using these attempts because of their short-term nature. The tools utilized are shown in Table 1 as follows: Microglass fiber, purpleAir sensor, Aerosol Mass Monitor, AQMesh, P-sensor, and handheld air tester (CW-HAT 200), in that order. No Airly low-cost sensor (LCS) was used in any of the studies.

There is currently no trustworthy estimate of the effects of ambient air pollution in Lagos using Airly LCS, particularly in the Mafoluku neighborhood, despite mounting worries about the city's air pollution problems. By giving a concise summary of the ambient PM_{10}, $PM_{2.5}$, and PM_1 pollution using Airly LCS and the toxicity potential of the region, this report fills in these gaps.

Table 1. Air Pollution studies including location, title of studies, tool used for assessment, and key findings.

City (Country)	Title of studies	Instrument Used	Key findings	Reference
Lagos Mainland, Nigeria	Air Pollution Monitoring Around Residential and Transportation Sector Locations in Lagos Mainland	Handheld air tester (CW – HAT 200)	PM_{10} 43.34 – 127.21 µg/m³, and $PM_{2.5}$ 20.32 – 69.05 µg/m³	[10]
Lagos, Nigeria	The Health Cost of Ambient Air Pollution in Lagos	air samplers	Ikeja (77 µg/m³), Mushin (85 µg/m³) and Ikoyi (41 µg/m3)	[1]
Allen Avenue, Kolington, Isheri, Badagry, Opebi, Eti-Osa, Ajeniya, Awolowo, Orile, and Ajegunle, Lagos, Nigeria	Concentrations and health risks of particulate matter ($PM_{2.5}$) and associated elements in the ambient air of Lagos, Southwestern Nigeria	Aerosol Mass Monitor	$PM_{2.5}$ Allen Avenue (16.83 µg/m³), Kolington (15.85 µg/m³), Isheri 27.22 µg/m³), Badagry (5.36 µg/m³), Opebi (17.85 µg/m³), Eti-osa (31.32 µg/m³), Ajeniya (34.63 µg/m³), Awolowo (17.31 µg/m³), Orile (28.48 µg/m³), Ajegunle (29.65 µg/m³)	[13]
Ikeja, Maryland, Ojodu, Eti-Osa, and Opebi, Lagos, Nigeria	Preliminary Assessment of Air Pollution Quality Levels of Lagos, Nigeria	Satellite Data	$PM_{2.5}$ and PM_{10} over Ikeja was between 20–123 µg/m³ and 30–176 µg/m³ ; Maryland was between 22–120 µg/m³ and 33–173 µg/m³ ; Ojodu was between 17 µg/m³ –81 µg/m³ and 27–121 µg/m³ ;	[9]

			and Eti-Osa was between 5 μg/m³ –212 μg/m³ and 9 μg/m³ –298 μg/m³ . In Opebi, however, $PM_{2.5}$ and PM_{10} were between 26–163 μg/m³ and 40–241 μg/m³, respectively.	
University of Lagos, Akoka and Agege, Lagos	The level $PM_{2.5}$ and the elemental compositions of some potential receptor locations in Lagos, Nigeria	Aerosol samples were captured on a microglass fiber particle filter and the $PM_{2.5}$ determined gravimetrically	$PM_{2.5}$ 6 to 14 μg/m³ in Unilag and Agege respectively	[11]
Victoria Island (in Lagos, Nigeria) and Melen Mini-Ferme, (Yaoundé, Cameroon	Assessment of the Temporal and Seasonal Variabilities in Air Pollution and Implications for Physical Activity in Lagos and Yaoundé	AQMesh	Mean $PM_{2.5}$ 26 μg/m³ (Lagos) and 28 μg/m³ (Yaoundé)	[14]
Lagos, Rivers and Abuja namely Lekki, Port Harcourt and Lugbe	Atmospheric Physics; Air Pollution Monitoring and Analysis Using Purple Air Data	PurpleAir sensors.	The results indicate that Port Harcourt has the greatest concentration of particulate matter among the research regions, afterwards Lugbe, which has an average level of Standard Indoor (CF1) $PM_{2.5}$ & $PM_{10.0}$ of 12 weeks. concentration and Standard Outdoor or Atmospheric(ATM) $PM_{2.5}$ concentration to be 87.80 μg/m³ , 101.76 μg/m³ and 63.15 μg/m³ respectively while Abuja has an average $PM_{2.5}$ CF1, $PM_{10.0}$ CF1 and $PM_{2.5}$ ATM values of 70.51 μg/m³ , 86.21 μg/m³ and 52.07 μg/m³ respectively	[12]
Akure, Nigeria	Multi-Year Continuous Observations of Ambient $PM_{2.5}$ at Six Sites in Akure, Southwestern Nigeria	P-sensors	Compared to the rainy season, $PM_{2.5}$ levels were much higher during the dry season (November–March), frequently	[15]

			surpassing dangerous levels (over 350 μg/m³).	

2. Materials and Methods

Sampling location Mafoluku, Lagos, in the Southwest area of Nigeria (6º33'32.1'' N 3º19'35.5'') was the urban site where the air quality was evaluated (Figure 1). The study is being conducted in Lagos, the former capital of Nigeria. It has both domestic and international airports, businesses, marketplaces, office and residential buildings, and a lot of traffic, both people and cars. Garbage is produced here. Residents have had trouble disposing of these trash. From this point of view, there is a reason for pollution from all the different activities. There is a lack of data in the Mafoluko area, Oshodi, where this study was conducted.

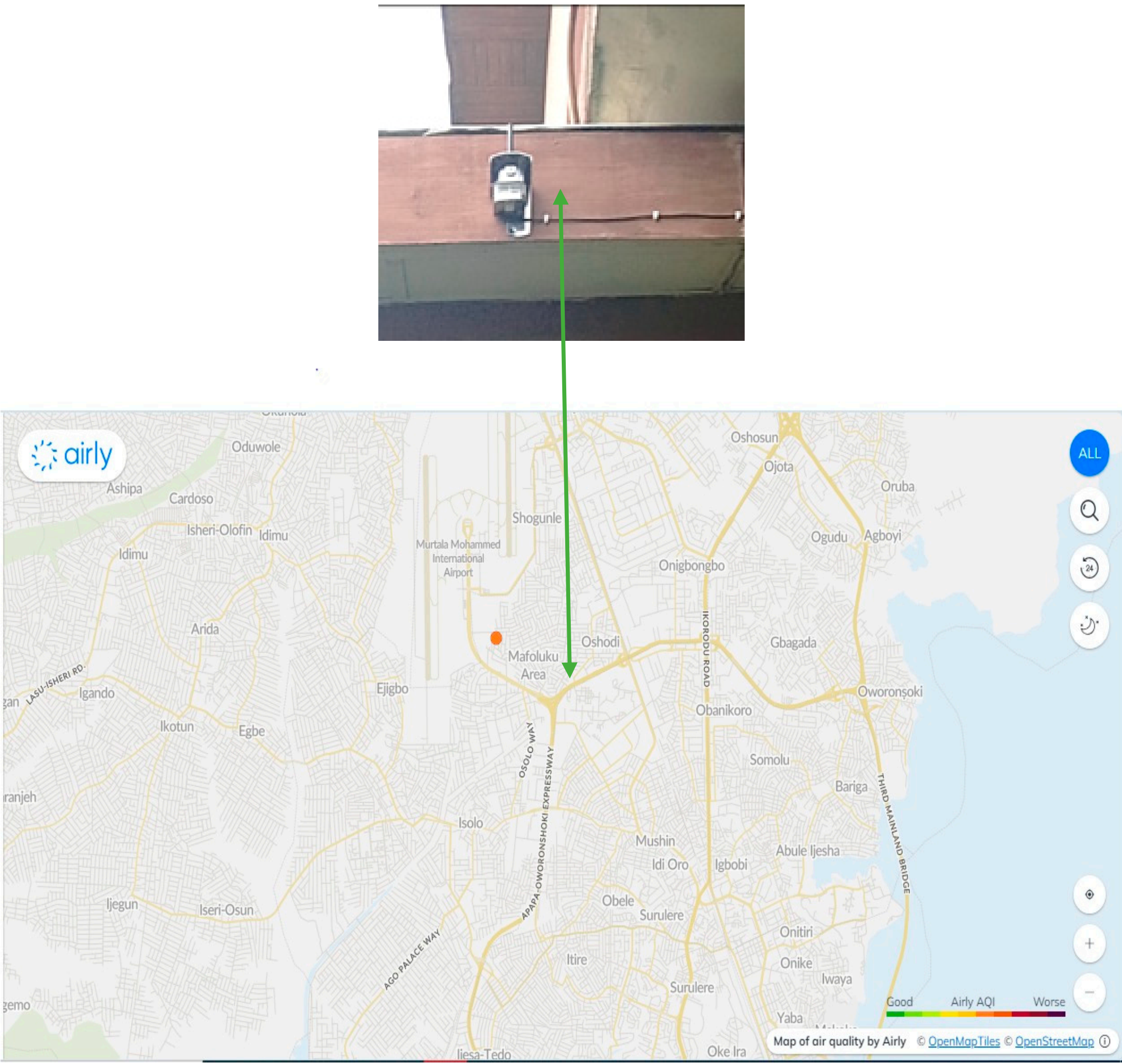

Figure 1. The location of the assessment.

Meteorology of Lagos, Nigeria

One of the world's most crowded cities is Lagos, the former capital of Nigeria. There are almost 9 million people living in the 1,171.28 km² area. Lagos is situated on the Atlantic Ocean coast in Southwest Nigeria at 6°27′18″N 3°23′03″E. It is Nigeria's industrial and commercial hub. Nigeria generally has high temperatures and a humid climate. Nigeria has two distinct seasons based on its weather: the wet (raining) season (November to March) and the dry (harmattan) season (April to October). Lagos experiences hot, dry summers and moderate winters due to its Mediterranean

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climate. June through August is the ideal time osf year to visit Lagos if you enjoy the sun. With an average daily high of 28 °C and an average low of 19 degrees, July is the hottest month of the year.

Assessment

Using the standard particulate matter assessment technique, an assessment of air quality indicators was carried out from September to November of 2024. Data was collected in real time for a whole day. Figure 2 displays the Airly Sensor (GSM-PM-PTH 2965, Poland) that was utilized in this investigation. The sensor analyzes (real-time dashboard, report generator, social effect tracker), measures (PM_1, $PM_{2.5}$, and PM_{10}) each have a resolution of ± 1 µg/m³), and impacts (air pollution warning, mobile app, forecast, and air quality map). It weighs 440g, is made of stainless steel, and may be powered by a mobile battery, solar power, or commercial energy.

Figure 2. The Airly LCS used for the assessment.

The sampling interval is 1-2 seconds, while the averaging and sending intervals are 5 minutes. Map.airly.org, the Airly website, provided access to the data. Since the research area was clear of obstructions, the sensor's accuracy was good. Using the manufacturer's handbook, installing the sensor was simple. It was suspended at least 1.8 meters above the ground and connected to a standard electrical outlet. Calibrated measurements appeared on the Airly Data Platform 48 hours later. The inexpensive sensor measured wind speed, wind bearing, and pressure, among other meteorological characteristics. CSV files of the results were downloaded.

Using the following formula, the toxicity potential (TP) for $PM_{2.5}$ and PM_{10} at the outdoor sampling site is as follows [16,17]:

$$\text{Toxicity Potential (TP)} = \frac{Cp}{Sp}$$

In this case, Sp is the usual recommendation value of 25 μg/m³ for $PM_{2.5}$ and 50 μg/m³ for PM_{10}, while Cp is the measured concentrations of the pollutants [18]. A TP score greater than one indicates that the chosen pollutant may pose a health concern in a certain area.

Backward air-mass trajectories analysis

In order to determine the origin of the particulate matter approaching the sampling location of the residential area in Lagos, Nigeria, a backward air-mass trajectory analysis that reached Lagos at 500 meters above ground level was computed using Hybrid Single-Particle Lagrangian Trajectory (HYSPLIT, NOAA/ARL) [19].

Statistical analysis

To evaluate the data at the location, the mean and standard deviation of each air quality indicator ($PM_{1.0}$, $PM_{2.5}$, PM_{10}, wind speed, wind bearing, and pressure) were computed. Statistically significant seasonal differences were evaluated at a 95% confidence level (p value = 0.05) using a paired t test. To determine whether PM levels and the meteorological parameter were related, the Pearson product correlation coefficient (r) was calculated. While Minitab software performed various computations, Excel 2013 was used to create the visual depictions.

3. Results

It is quite concerning how careless most people are with their air and air quality. Ambient air pollution has been largely caused by unmonitored human activity and noncompliance with preventive measures [12]. According to data (Table 2) gathered over a two-month period, the mean for PM_{10}, $PM_{2.5}$, and PM_1 was 36.32, 34.83, and 34.39 μg/m³, respectively. For Lugbe (11.42 – 156.73 μg/m³), Lagos – Ikeja and Maryland – 22–173 [9, and Lagos Mainland – 43.34 – 127.21 μg/m³, the results are consistent with PM_{10} measured by Lawal and Mohammed, [12]. Although the maximum $PM_{2.5}$ in this study was higher than that of Obanya et al. [10], the mean $PM_{2.5}$ value (34.83 μg/m³) was higher than those reported by Alani et al. [11], Popoola et al. [14], and Yahaya et al. [13]. The study's mean results were lower than those published by Croitoru et al. [1]. The various activities, weather conditions, and assessment methods could all be contributing factors to the discrepancies. Kurtosis (11.38), Skewness (2.92), CV% (53.92), StD (18.54), and PM_1 mean are 34.39 μg/m³. The lowest and greatest values were in good agreement with those of Emekwuru and Ejohwomu [20], which ranged from 3.7 to 139.3 μg/m³.

Table 2. Basic Description of Data obtained from the Location.

Variable	Mean	StD	CV (%)	Min	Q1	Median	Q3	Max	Skewness	Kurtosis
PM10	36.32	18.57	51.13	19.45	25.26	30.06	40.38	154.84	2.92	11.24
PM2.5	34.83	18.58	53.35	18.01	23.51	28.63	38.74	154.02	2.92	11.32
PM1	34.39	18.54	53.92	17.58	23.01	28.30	37.99	153.74	2.92	11.38
Wind Speed	8.56	3.19	36.84	2.08	6.17	8.46	11.03	16.98	0.28	-0.59
Wind Bearing	224.62	36.71	16.34	10.20	206.49	217.66	137.11	358.61	0.23	4.73
Pressure	1013.3	1.73	0.17	1008.6	1012.3	1013.4	1014.6	1017.5	-0.22	-0.29

The PM_{10}, $PM_{2.5}$, and PM_1 comparisons with WHO recommendations are displayed in Figure 3. Based on the averaged data for the study site, the average concentrations for PM_{10}, $PM_{2.5}$, and PM_1 were determined to be 36.12 μg/m³, 34.83 μg/m³, and 34.39 μg/m³, respectively. $PM_{2.5}$ was around 232.23% of the WHO air quality standard annual value (5 μg/m³), and PM_{10} was over 80% of the WHO air quality standard annual value (45 μg/m³). The value for PM_1 was not computed since the WHO standard was not available. These values (36.12, 34.83, and 34.39 μg/m³) were higher than the annual

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average value from June 2021 and May 2022 at an urban site in Lagos (26 µg/m³), but they were close to the lower end of the annual mean values (from 40 to 135 µg/m³) at six sites in Lagos from August 2020 to July 2021 [21]. This implied higher local emission contributions at a particular industrial location in Lagos as opposed to the Mafoluku study site.

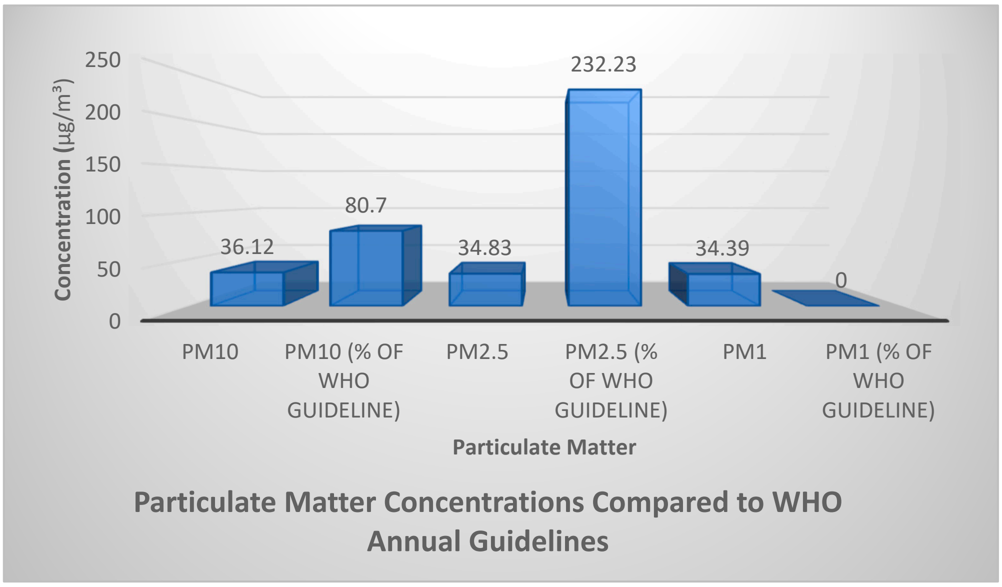

Figure 3. Particulate Matter Concentrations Compared to WHO annual Guidline.

Particulate matter mass ratio of the PM indicators

The inter-particulate ratios were assessed in September and November to have a better knowledge of particulate matters in the outdoor environment (Figure 4). $PM_{1.0}/PM_{2.5}$, $PM_{2.5}/PM_{10}$, and $PM_{1.0}/PM_{10}$ had average ratios of 0.98, 0.95, and 0.93, respectively. In Hong Kong, Cheng et al. [22] found that $PM_{1.0}$ made up a significant amount of $PM_{2.5}$ and $PM_{2.5}$ made up a significant fraction of PM_{10}. According to their findings, $PM_{1.0}$ accounted for 68 to 84% of $PM_{2.5}$ and $PM_{2.5}$ for 73 to 82% of PM_{10}. Nonetheless, the ratios showed that mechanically generated aerosols or secondary aerosol particles contributed significantly to IAQ indicators, particularly for $PM_{1.0}$ and $PM_{2.5}$. During the assessment period, there was some variation in all three ratios ($PM_{1.0}/PM_{2.5}$, $PM_{2.5}/PM_{10}$, and $PM_{1.0}/PM_{10}$) at the sampling locations. The ratios do not significantly differ from one another.

Because PM_1-sized particles are more likely than $PM_{2.5}$ or coarse (PM_{10})-sized particles to enter the lungs through the nose and throat, they are researched here because they are at least as dangerous. According to the measured mean PM_1/coarse particle concentration ratios (PM_1/PM_{10}), a significant fraction of the particulate concentrations in this region are caused by combustion and related processes that generate extremely small particles. Saetae et al. [15] found a ratio of 0.63, but this was over the course of 2.5 months during the dry season; these kinds of research are uncommon in this area. While fine particles are primarily created in the atmosphere by chemical reactions and organic substances, coarse particles are often created by mechanical processes like grinding or wind blowing. Accordingly, a high $PM_{2.5}/PM_{10}$ ratio suggests that fine particles, like those from combustion sources, contribute significantly to the PM concentration, while a low ratio suggests that coarse particles, like those from road dust or re-suspended soil, contribute more to the PM concentration [23].

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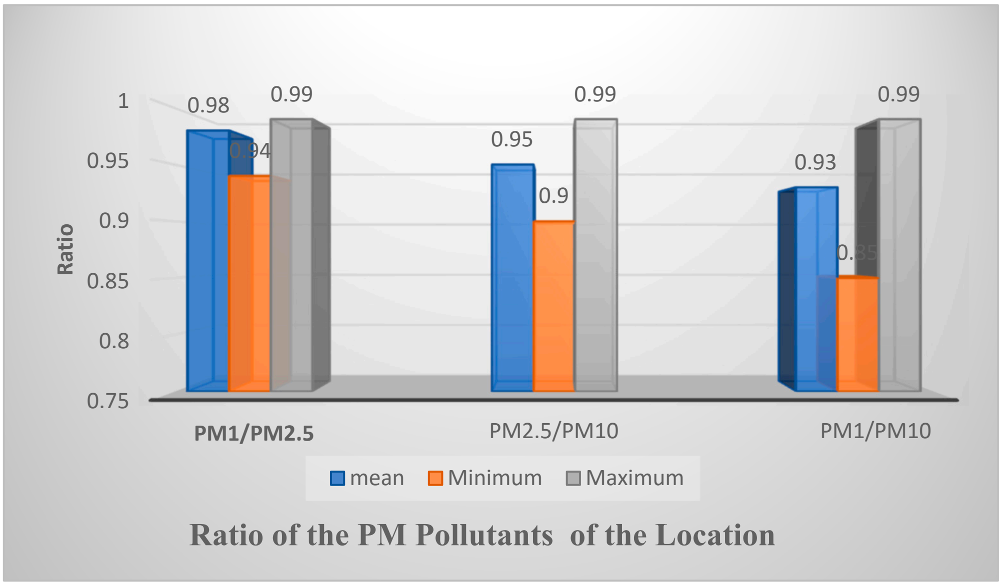

Figure 4. Ratio of the PM Pollutants of the Location.

Toxicity potential

According to Ayodele et al. [17], toxicity potential is a quantitative toxic equivalence that is helpful in determining the harmful impact that air pollution emissions from various hospital operations have on human health. A TP score greater than one indicates that the chosen pollutant may pose a health concern in a certain area. Both the annual and daily TP values of $PM_{2.5}$ and PM_{10} were higher than 1 in the area. $PM_{2.5}$'s values varied from 3.6 to 30.8 per year and daily from 1.2 to 10.27, while PM_{10}'s values ranged from 1.3 to 10.32 per year and daily from 0.43 to 3.44. Because standard guidelines were not available, the TP of PM_1 was not calculated (Figure 5). With the exception of a few number of instances in which the TP was less than 1, this indicated that the TP values for PM_{10} daily were below 1.

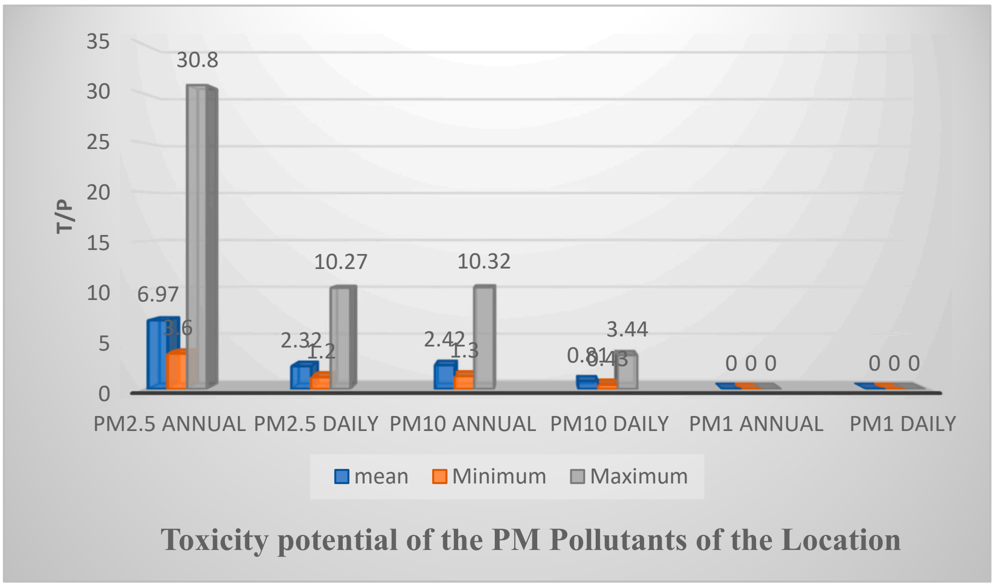

Figure 5. Toxicity Potentials of the PM Pollutants of the Location.

The association between climatic characteristics and PMs concentrations in the outdoor sampling location during the assessment periods was examined using the Pearson product-moment correlation coefficient (PCC) (r value) at a 95% significance level. The relationships between particulate matter and meteorological parameters are displayed in Table 3 and Figure 6. There was

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an extremely high positive connection between $PM_{1.0}$, $PM_{2.5}$, and PM_{10}. Although they are weak, there are relationships between the PMs and the climatic data as well. The following is a presentation of the correlation coefficient threshold definitions that were modified from Schober et al. [24]:

Observed Correlation Coefficient, r	**Interpretation**
0.00 to 0.10	Negligible correlation
0.10 to 0.39	Weak correlation
0.40 to 0.69	Moderate correlation
0.70 to 0.89	Strong correlation
0.90 to 1.00	Very strong correlation

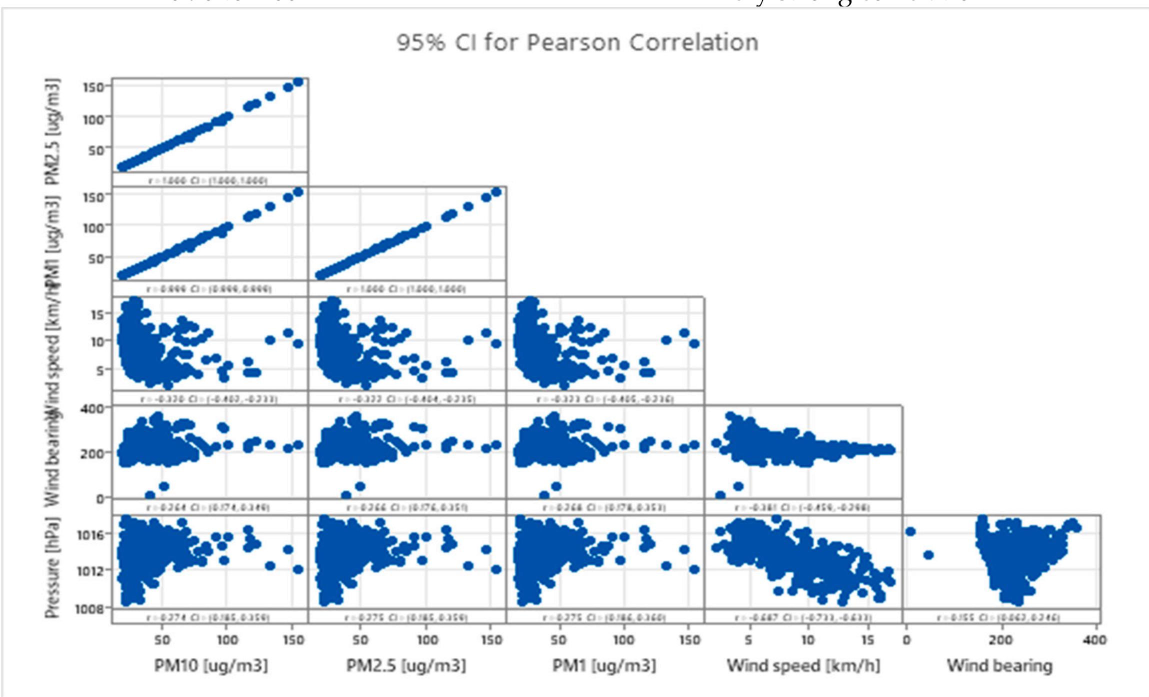

Figure 6. Matrix Correlation of the Particulate Matter and the Meteorological Parameters.

Table 3. Pearson Csorrelation of the Particulate Matter and the Meteorological Parameters.

	PM_{10}	**$PM_{2.5}$**	**PM_1**	**Wind speed**	**Wind bearing**
PM_{10}	1.000				
$PM_{2.5}$					
PM_1	0.999	1.000			
Wind speed	-0.320	-0.322	-0.323		
Wind bearing	0.264	0.266	0.268	-0.381	
Pressure	0.274	0.275	0.275	-0.687	0.155

The three size fractions of particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}) have a strong positive connection, with r values ranging from 0.80 to 0.95 in the winter, according to comparable findings published by Abulude and Abulude [25] and Emekwuru and Ejohwomu [20].

The temporal trend of PM_1, $PM_{2.5}$, and PM_{10} concentrations during a 24-hour period is displayed in Figure 7. The mean concentrations measured hourly on various days are used to compute the trend. In general, there is a greater fluctuation in particulate matter concentration during the day than at night. On the other hand, the nighttime concentration of particulate matter is higher than the daytime concentration. The reason for this could be that the atmosphere is more stable at night because of the lower temperatures, whereas during the day the planet is warmed by sunshine, which improves atmospheric mixing. At higher elevations, PM increases [26]. Additionally, the range of PM concentrations across different altitudes decreases at night when the mixing layer height (MLH) decreases [27]. Because particulate matter may more readily travel to higher altitudes in an unstable atmosphere, the difference in particulate matter concentration at different altitudes during the day is more noticeable, even though the concentration of particulate matter is larger at night.

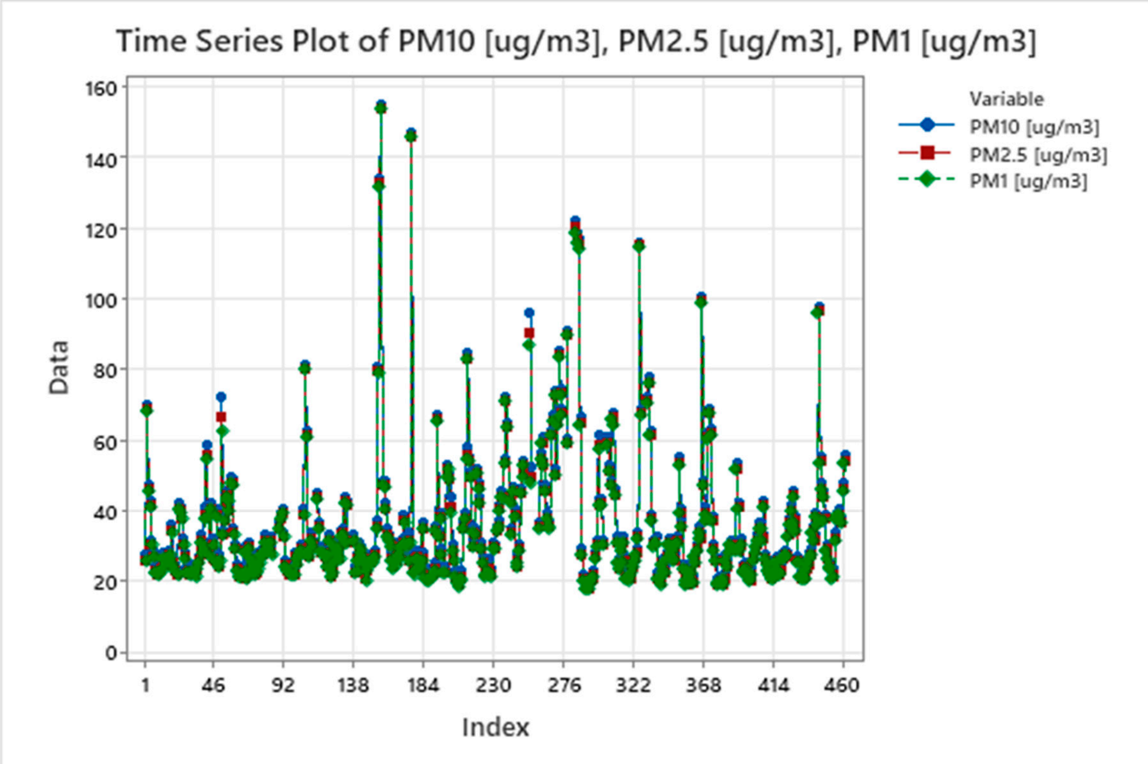

Figure 7. Times Series Plot of the Pollutants at the Location.

Backward air-mass trajectories analysis

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) backward trajectory model [28,29] was used to calculate the directions and distances of the sources of the air parcel over the air pollutants measurement site in this study. The simulation results show that Southwestern desert winds contributed to the air mass over the site during the assessment. This difference between higher and lower PM levels were noted at Ile Ife, which is roughly 210 kilometers northeast of the Akoka Lagos sites [30]. According to Figure 8, the low-level air mass primarily arrives from the south and travels a comparatively short distance throughout the September–November season. Natural marine aerosols are abundant in the southerly air mass (originating from the Atlantic Ocean). Lower particle concentrations were observed throughout the research period as a result of the relatively fresh air mass and heavy rainfall, which considerably reduces the washout effect.

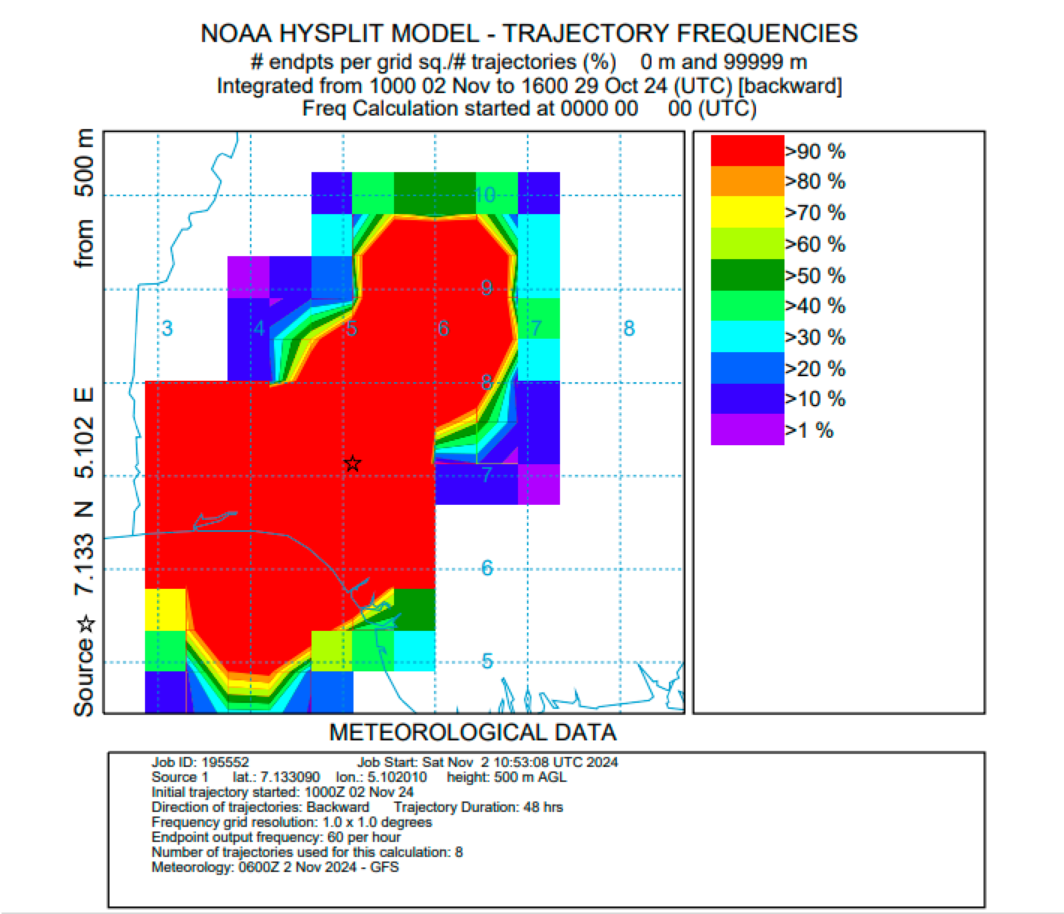

Figure 8. Integrated Trajectory (HYSPLIT) backward trajectory of the Location.

Author Contributions: "Conceptualization, FOA. and A.A.; methodology, FOA.; software, SDO.; validation, FOA, AA, SDO.; formal analysis, SA.; investigation, FOA.; resources, SA.; data curation, SDO, SA.; writing—original draft preparation, FOA.; writing—review and editing, AA, SDO, KMA.; visualization, SA.; supervision, KMA; project administration, FOA, KMA; gift acquisition, FOA. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

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