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GEOGRAPHICAL COMPARATIVE ANALYSIS OF PARTICULATES MATTERS EMITTED FROM LAFARGE CEMENT FACTORY

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ABSTRACT
Particulate matter (PM) pollution significantly threatens human health and the environment. $PM_{2.5}$ and PM_{10} have emerged as critical air quality indicators and potential health risks among various PM categories. The study elucidates the particle size characteristics of $PM_{2.5}$ and PM_{10}. This geographical comparative analysis examines the differences in the amount of $PM_{2.5}$ and PM_{10} along the three (3) routes leading up to the Lafarge Cement Factory, Sagamu, Ogun State. Aeroqual S530 was used for nine (9) months to get the particulate concentrations of the particulates. Results from the study found significant differences in $PM_{2.5}$ concentrations between the Ikorodu and Abeokuta routes, with higher levels near the cement factory. Similarly, PM_{10} levels varied across the area, peaking near the factory in the northeastern part of the study area. The eastern part of the Sagamu local government area was identified to be experiencing the highest $PM_{2.5}$ concentrations, potentially influenced by multiple sources, including vehicular traffic and industrial activities, in addition to proximity to the Ikorodu route and cement factory. PM_{10} concentrations vary across the area, with higher levels near the cement factory and lower concentrations in the western and northeastern parts, consistent with previous research. In conclusion, this study highlights the significant differences in $PM_{2.5}$ and PM_{10} concentrations along routes leading to the Lafarge Cement Factory in Sagamu, Ogun State, underscoring the importance of considering multiple factors when assessing and mitigating particulate matter pollution in affected areas. Conclusively, the research showed how pollution levels change across locations. It found that areas closer to the factory had significantly higher concentrations of particulate matter.

Keywords: Air pollution, Cement Factory, Environment, Particulate Matter, Sagamu

1. INTRODUCTION

There have been a lot of diseases and illnesses associated with air pollution. The diseases/illnesses range from respiratory disorders to heart imbalances [1, 2]. Cement factories contribute so much to the atmospheric pollution that emanate from every production stage [3]. The pollution from the cement factory affects the factory workers and residents close to the factory; older people and very small children are more vulnerable. Particulate matter (PM) is a complex mixture of solid and liquid particles suspended in the air [4]. These particles vary in size, composition, and origin [5]. They can be categorized based on their aerodynamic diameter, determining how far they can penetrate the respiratory system. PM is generated from both natural and human-made sources. Natural sources include dust, pollen, sea salt, wildfires, and volcanic eruption particles. Human-made PM sources include industrial emissions, vehicle exhaust, construction activities, power plants, and the burning of fossil fuels [6]. The size of particulate matter is an important factor in understanding its health effects. PM is classified into different size fractions, such as PM_{10} (particles with a diameter of 10 micrometres or smaller) and $PM_{2.5}$ (particles with a diameter of 2.5 micrometres or smaller) [7]. Fine particles ($PM_{2.5}$) are of particular concern because they can penetrate deeply into the respiratory system and even enter the bloodstream, posing health risks [8]. Exposure to high levels of particulate matter can adversely affect human health. Inhalation of PM can cause respiratory symptoms such as coughing, wheezing, and shortness of breath. Long-term exposure to elevated levels of PM has been associated with increased risks of respiratory and cardiovascular diseases, including asthma, bronchitis, heart attacks, and premature death [9]. Due to its impact on air quality and public health [10], monitoring and controlling particulate matter pollution is an important aspect of environmental management and public health policies. This involves implementing measures to reduce emissions from various sources, improving air quality monitoring systems, and raising awareness about the health risks associated with particulate matter exposure [11, 12].

1.1 Review of Literature

The global demand for cement production is increasing, leading to large-scale production. The industry contributes 12%-15% of all available industrial energy and almost 5% of global greenhouse gas emissions [3]. This makes it the second-largest contributor globally after the steel industry. Cement industries significantly contribute to global production and environmental pollution as the processes involved emit Particulate matter, CO_2, NO_X, and SO_2, amongst others. Particulate matter emissions from cement production are influenced by various factors [13]. These factors vary from the chemical composition and properties of raw materials [14] to the type and design of kilns used and the efficiency of combustion processes for fuel utilization [15]. Implementing emission control technologies such as electrostatic precipitators or bag filters highlights the complexity of mitigating these emissions and the need for comprehensive management strategies within the cement industry [16].

Particulate matter emitted from cement plants exhibits a diverse size distribution ranging from coarse particles (PM_{10}) to fine particles ($PM_{2.5}$) [17, 5]. They are composed primarily of mineral components such as calcium carbonate, silica, alumina, and iron oxide [18], often accompanied by trace elements including heavy metals [19], with characteristics influenced by the specific processes involved, raw material properties, and emission control measures employed within the cement manufacturing facilities. Research efforts [20, 21, 9] have proven that exposure to particulate matter emitted from cement factories can lead to adverse health effects, including respiratory issues such as asthma exacerbation, bronchitis, and cardiovascular diseases. Fine particles ($PM_{2.5}$) are particularly concerning due to their ability to penetrate the lungs and bloodstream [22]. Particulate matter emissions from cement plants can degrade air quality by contributing to haze, smog, and visibility impairment, posing risks to human health and ecosystems [23, 10]. Also, the deposition of particulate matter onto soil surfaces can alter soil chemistry and fertility, potentially affecting agricultural productivity and ecosystem health [6].

According to research, monitoring and measuring particulate matter emissions from cement factories [11, 24, 12] typically involves a combination of stack sampling, continuous emissions monitoring systems (CEMS), and dispersion modelling. Stack sampling techniques, such as EPA methods, collect samples of emissions from stack outlets for laboratory analysis, providing direct measurements of particulate matter concentrations [25]. CEMS offer real-time stack emissions monitoring, allowing for continuous data collection and immediate feedback on compliance with regulatory standards. At the same time, dispersion modelling estimates ambient concentrations and potential impacts on surrounding communities [26]. Dispersion modelling estimates ambient concentrations and potential impacts on surrounding areas, offering a cost-effective way to assess overall emissions' environmental effects but relying heavily on accurate input data and assumptions [27].

2. MATERIALS AND METHOD

Aeroqual S530 was used to determine the concentration of the particulates. The three major routes leading to the cement factory were used as the source of data collection. It was carried out for nine (9) months, spanning May 2020 to January 2021. Monthly data collection of the particulates ($PM_{2.5}$ and PM_{10}) was used. The Lafarge cement factory is situated in Sagamu, Ogun state. The factory is a major source of employment for the residents around Akarigbo Local Government Area (LGA), Sagamu. To ensure data accuracy, all equipment was pre-calibrated. For future analysis, detailed readings were meticulously recorded monthly in an Excel spreadsheet. This spreadsheet was then used to calculate both standard deviation and average concentration values.

2.1 Procedure for Using Aeroqual S530

Aeroqual Series 530 is a portable air quality monitor that can be used to measure the particulate matters of the environment. Ranging from $PM_{1.0}$ to PM_{10}, It has a switch that turns the equipment on or off and also a screen that displays values of particulate matters. Collection of data were done every Thursday for nine months, between 10:00 am and 5:00 pm. Each location, referenced geographically in Table 1, took roughly 15 minutes to measure. To minimize wind interference, measurements were conducted in open spaces.

2.2 The graphical location of the Routes

A handheld Garmin GPSMAP 64 GPS device was used to capture location coordinates and elevation.

Table 1: Graphical location of the Routes

Points	Ijebu-Ode Route 1	Abeokuta Route 2	Ikorodu Route 3
1	Landmark: Regal Height Distance:993.364 m (47°29′) Location: 754285, 569503	Landmark: MRS Petrol Station Distance: 844.874 m (40°43′) Location: 754254 , 569322	Landmark: Lafarge Ext. Gate Distance:280.456 m(291°31′) Location: 753717 , 568510
2	Landmark: UBA Distance:2480.878 m (54°16′) Location: 755063, 569487	Landmark: Abraham Tabernacle Distance:1616.593 m (26°17′) Location: 755063 , 559487	Landmark: SMC Company Distance:1729.084 m (244°09′) Location:752878 , 567206
3	Landmark: OPC Signboard Distance:4430.433 m (44°51′) Location: 755992 , 569867	Landmark: Imperial Parks Distance: 2618.744 m (24°44′) Location: 755992 , 569867	Landmark: Living Faith Church Distance:3460.470 m (250°47′) Location: 752475 , 5655503
4	Landmark: Terrazzo House Distance: 5921.462 m (41°09′) Location: 756690 , 569906	Landmark: Molariod Banquet Distance:3279.047 m(20°15′) Location: 756690 , 569906	Landmark: Sonia Foods Distance:5023.326 m (243°50′) Location:752475 , 565503
5	Landmark: NYSC Camp Distance: 7127.629 m (49°59′) Location: 756760 , 569563	Landmark: Ariya Hotel Distance:3244.487 m (14°07′) Location: 756760 , 569348	Landmark: Christ The Redeemer's Distance: 6475.780 m (241°38′) Location:750538 , 563072
6	Landmark: HID Awolowo Model Sch Distance: 9281.201 m (49°59′) Location: 756897 , 569348	Landmark: Redeemed Church Distance:3313.938 m(10°01′) Location:756877, 569348	Landmark: Thames Valley Distance: 8972.796 m(235°38′) Location:748549 , 561364

3. RESULTS AND DISCUSSION

Table 2: Comparative results of $PM_{2.5}$ and PM_{10} on the three routes

Month	IJEBUODE		ABEOKUTA		IKORODU	
	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
May	24.64	295.94	49.01	349.30	61.76	308.51
June	34.85	258.83	31.81	311.21	32.27	192.04
July	21.90	174.80	20.80	165.04	27.86	183.50
August	24.97	250.62	21.38	74.29	27.54	201.49
September	22.99	148.66	22.69	266.03	36.75	170.65
October	24.04	118.72	27.36	233.08	16.12	92.82
November	22.14	168.25	18.26	152.24	33.85	239.70
December	18.21	105.86	27.22	178.95	34.85	303.98
January	21.19	194.01	14.60	254.08	28.73	136.43

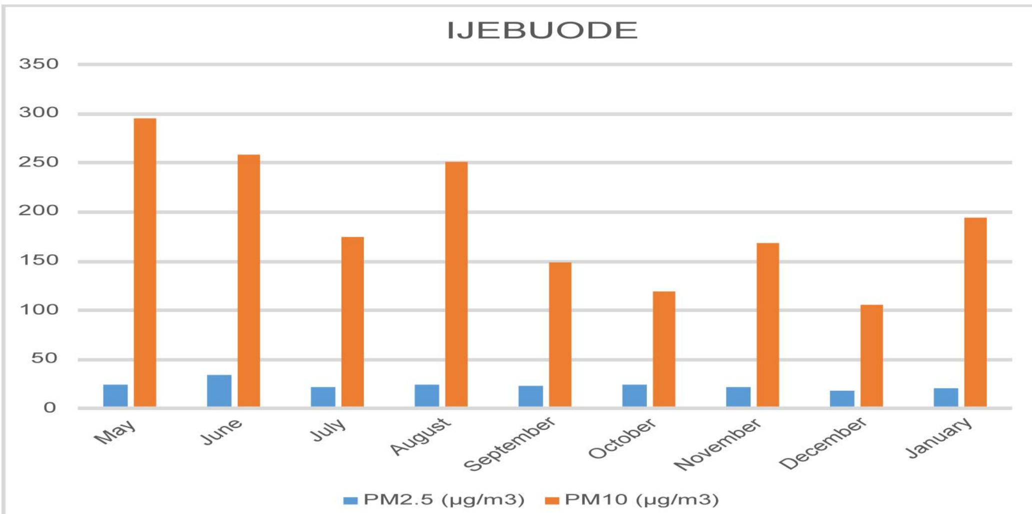
Source: Authors Fieldwork (2021)

This section contains the findings and the corresponding discusions. The highest recorded $PM_{2.5}$ concentration in the study area was 61.76 μg/m^3, observed on the Ikorodu route, at 280.46 meters from the cement factory. In contrast, the lowest $PM_{2.5}$ concentration measured in the study area was 14.60 μg/m^3, found on the Abeokuta route, 9281.2 meters from the cement factory. This data indicates a significant disparity in $PM_{2.5}$ levels between the two routes, with the Ikorodu route experiencing much higher pollution levels than the Abeokuta route.

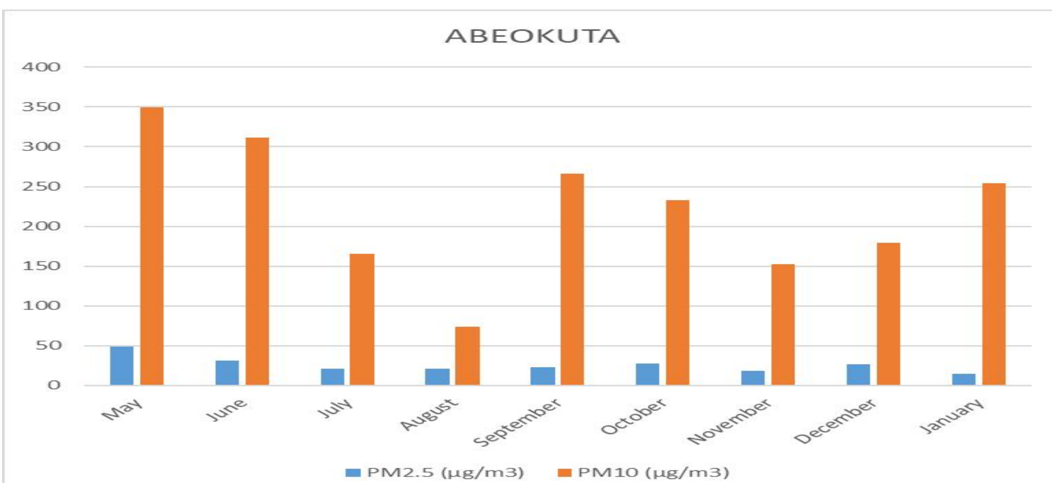
The observed disparity in $PM_{2.5}$ concentrations between the Ikorodu and Abeokuta routes could be attributed to their respective distances from the cement factory. The Ikorodu route, being closer to the factory, likely experiences higher pollution levels due to direct emissions and dispersion patterns. Similarly, PM_{10} pollutants spread across the study area with the highest value of 349.30 μg/m^3 on the Abeokuta route. The Abeokuta route also observed the lowest value of 74.29 μg/m^3. PM_{10} was highly concentrated around the northeastern part of the study area, particularly in communities near the Lafarge cement factory.

3.1 Comparative Graphs of $PM_{2.5}$ and PM_{10} on the three routes

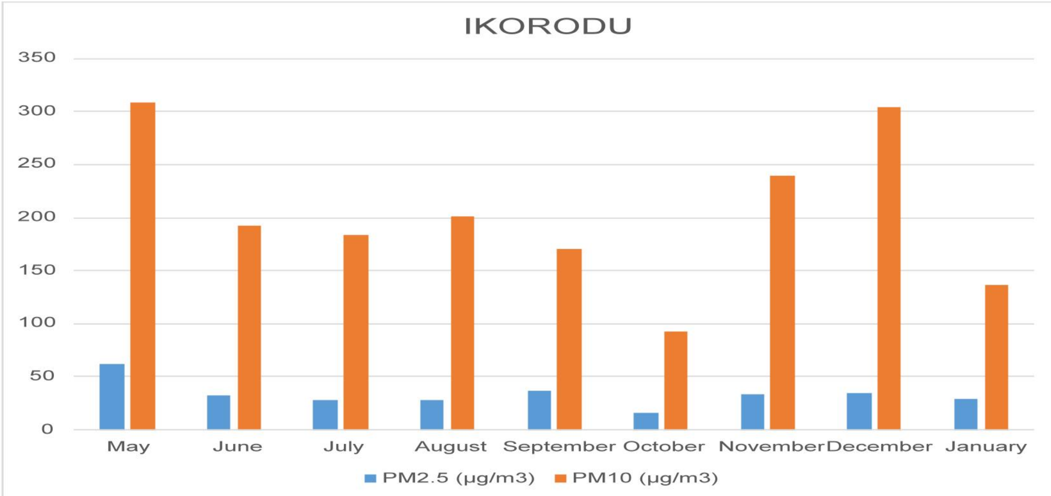
Figures 1-3 show that the values of PM_{10} were higher than the $PM_{2.5}$ along the three routes, however the values of PM_{10} in Abeokuta and Ikorodu routes were higher than the PM10 values in Ijebu-Ode route. This could be as a result of the location of the routes or closeness of the routes to the cement factory. Figures 4 and 5 show the spread of $PM_{2.5}$ and PM_{10} across the Sagamu local government area, and the green portion shows the safe area while the red area indicates the concentration of particulates. Additionally, the eastern part of the study area, where the highest $PM_{2.5}$ of the study area, where the highest $PM_{2.5}$ concentrations were recorded, may also be influenced by other sources of manmade pollution, such as vehicular traffic or industrial activities. These factors could contribute to the overall air quality in the area, exacerbating pollution levels.



Figuare 1: Comparative graph of $PM_{2.5}$ and PM_{10} on Ijebu Ode Route



Figuare 2: Comparative graph of $PM_{2.5}$ and PM_{10} on Abeokta Route



Figuare 3: Comparative graph of $PM_{2.5}$ and PM_{10} on Ikorodu Route

3.2 Geographical comparison of $PM_{2.5}$ & PM_{10}

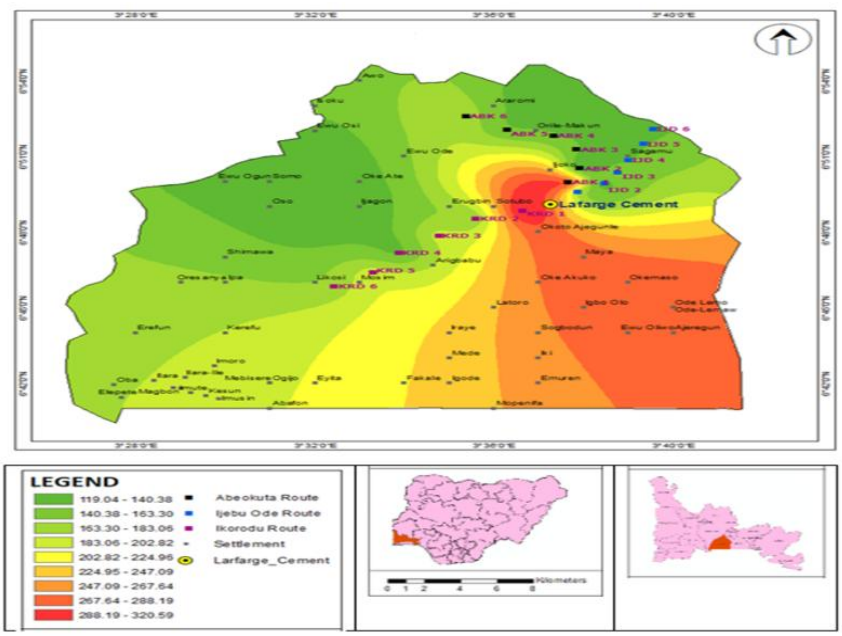


Figure 4: Spread of $PM_{2.5}$ across Sagamu Local Government

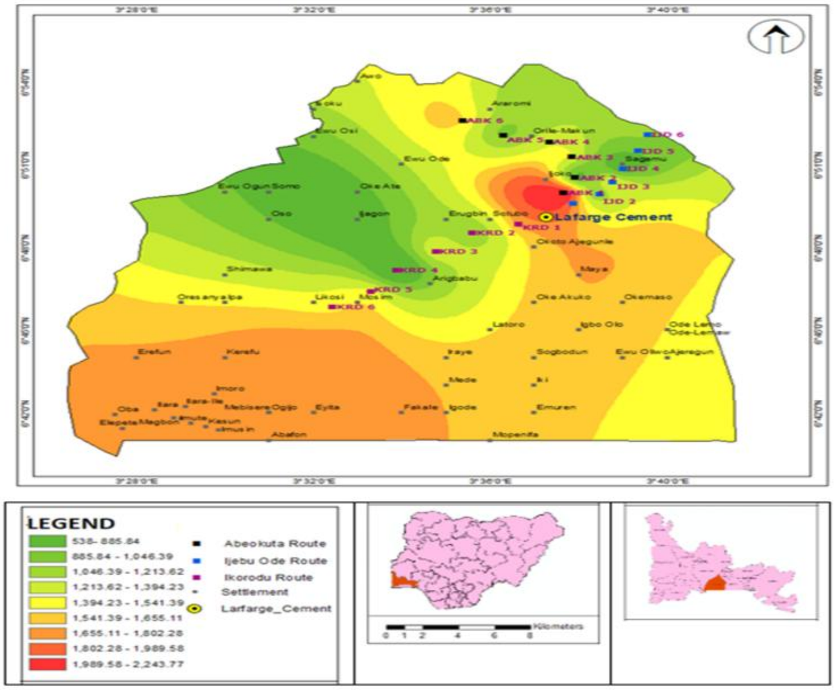


Figure 5: Spread of PM_{10} across Sagamu Local Government

The concentration of $PM_{2.5}$ in the eastern part of the study area may also be influenced by factors like wind patterns and geographical features, which can affect the dispersion of pollutants. Therefore, while proximity to the cement factory plays a significant role, other factors may contribute to the observed distribution of $PM_{2.5}$ concentrations across the study area. The concentration of $PM_{2.5}$ is highest in the eastern part of the study area, which is also closest to the Ikorodu route, suggesting a correlation between proximity to the route and the cement factory. This area likely experiences elevated pollution levels due to emissions from the factory and other sources, such as vehicular traffic and industrial activities along the Ikorodu route. The presence of multiple sources of pollution in the eastern part of the study area, combined with its proximity to the most polluted route (Ikorodu route), reinforces the notion that a combination of factors, including distance from pollution sources and local anthropogenic activities, influences pollution levels. This information underscores the importance of considering the cumulative effects of various sources of pollution when assessing air quality and implementing measures to mitigate pollution in the affected areas.

The values for PM_{10} showed that areas of low concentration were found around the western and northeastern parts of the study area. This suggests that PM_{10} concentrations vary within the study area, with the highest concentrations occurring near the cement factory and lower concentrations observed in other areas, particularly in the western and northeastern parts. This is in line with the findings in [17].

4. CONCLUSION

The comparative analysis between $PM_{2.5}$ and PM_{10}, focusing on their health impacts and implications for air quality management, has provided valuable insights into the complexities of particulate matter pollution and its effects on human health and the environment. The study revealed significant differences between $PM_{2.5}$ and PM_{10} in size characteristics, sources, health impacts, and monitoring and regulatory aspects. $PM_{2.5}$, being finer and more respirable, poses a greater risk to human health as it can penetrate deep into the respiratory system and even enter the bloodstream, leading to a range of respiratory and cardiovascular diseases. On the other hand, PM_{10}, although still harmful, is generally trapped in the upper airways and thus causes less severe respiratory effects than $PM_{2.5}$. The geographical analysis of $PM_{2.5}$ and PM_{10} concentrations around the Lafarge cement factory in Sagamu, Ogun state, provided valuable insights into the spatial distribution of particulate matter pollution. The data indicated significant variations in pollution levels across different routes, with closer proximity to the factory correlating with higher pollution levels.

5. RECOMMENDATION

The study underscores the critical importance of addressing particulate matter pollution, particularly $PM_{2.5}$, to safeguard public health and mitigate environmental impacts. An integrated approach encompassing monitoring, regulations, and pollution control measures is essential to effectively tackle the challenges posed by PM pollution.

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