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The Evaluation Of Suspended Particulate Matter (SPM) Associated With Artisanal Refineries In Bayelsa State, Nigeria

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ABSTRACT

The growth of artisanal refineries in Nigeria's Niger Delta is posing a significant public health risk due to the release of toxic fumes with suspended particulate matter. This study evaluated the concentration of SPM, which was measured at six locations, including a control station, using a digital portable hand-held meter (AEROCET-513, Metone instrument). Results showed that the SPM ranges were: PM1.0 (17.68–28.99 µg/m^3), PM2.5 (23.48–39.69 µg/m^3), PM4.0 (35.84 –58.18 µg/m^3), PM7.0 (45.63–78.57 µg/m^3), PM10 (69.16–117.67 µg/m^3), and Total Suspended Particulate Matter (TSP) ranging from 171.37–257.52 µg/m3. Compared to all sites in the study area (L1–L5), the control site (LX) had the lowest concentration of particulate matter ($p<0.05$). The study found that artisanal refineries in the Niger Delta emit higher levels of particulate matter (SPM), exceeding WHO and national air quality standards. These emissions are attributed to anthropogenic activities aided by some meteorological indicators. The study calls for policies to prevent these activities and encourage modular refineries to create employment opportunities for the youth in the Niger Delta. Government, community leaders, regulators, and stakeholders are all needed to address this issue.

Keywords: artisanal refineries, Suspended particulate matter, Air quality, Pollution, Crude oil

INTRODUCTION

The Niger Delta is one of the main industrial hubs in Nigeria, with a huge reserve of hydrocarbon resources. Beyond the economic considerations of crude oil theft in Nigeria, the refining of crude oil using local fabrications by artisans has become a mainstay and source of livelihood among the youth of the Niger Delta (Igben, 2021). Unfortunately, during production, there are gross shortfalls in quality control and assurance, resulting in the release of toxic gases that foul ambient air quality. Some toxic gases released during production include oxides of nitrogen (NOx), carbon monoxide (CO), oxides of sulphur (SOx), and suspended particulate matter (SPM). There is a need to address the issue of small-scale refineries that use outdated and harmful technologies, which negatively impact the environment (Onuh *et al*., 2021).

Suspended Particulate Matter (SPM) comprises tiny solid, liquid, or gaseous particles aerosols. These particles can originate from either human activities (anthropogenic) or natural sources (lithogenic) (Brown *et al*., 2013). Fine particulate matter typically has a diameter of 2.5 µm or less, while coarse particulate matter ranges from above 2.5 - 10 µm in diameter (US-EPA, 2016). Other particulate matter types include thoracic and respirable particles (Brown *et al*., 2013). The sources of atmospheric particulate matter are diverse and can be influenced by various environmental factors, including meteorological conditions of the area affected (Angaye & Abowei, 2018).

According to the World Health Organisation (WHO, 2013), PM1.0 is fine and smoother in texture and classified as a group 1 carcinogen - the most lethal category of carcinogens. Their small size enables them to penetrate deep into our respiratory system, bypassing our natural defences and causing DNA mutations (US-EPA, 2010; Ite *et al*., 2013). The United States Environmental Protection Agency (USEPA, 2007) classifies particulate matter as one of the six criteria pollutants. The USEPA has established primary standards for both PM10 and PM2.5 to safeguard human health. The standard for PM10 is 150 $\mu g/m^3$ for 24 hours, while the standard for PM2.5 is 35 $\mu g/m^3$ annually (Vallius, 2005).

Based on literature findings (Shah *et al*., 2013), a significant proportion of these deaths, around 2.1 million instances, can be attributed to fine particle pollutants. These health concerns encompass early death in persons with cardiovascular or pulmonary disease, worsened asthma, myocardial infarctions, arrhythmia, reduced pulmonary function, and heightened respiratory symptoms. The rapid expansion of artisanal refineries in Bayelsa State has generated significant apprehension across the community regarding their adverse effects on the environment and human health. Furthermore, there is a dearth of data on the concentration of SPMs generated by these operations. Therefore, this study is essential for characterizing the concentration of SPMs resulting from the artisanal refining of crude oil in Bayelsa State.

MATERIALS AND METHOD

2.1 Study area

This study examines Bayelsa State, a coastal state in Nigeria, with a population of 2.3 million. The state is known for its diverse aquatic habitats and waterways, and its shallow aquifer, which supports agricultural industries. The region experiences two distinct seasons: arid and humid, with the dry season lasting from November to March and the rainy season from April to October. Bayelsa State is characterized by its diverse ecological system and abundant natural resources.

2.2 Sampling sites

In Bayelsa state, there are multiple artisanal refinery sites. However, the sampling sites were chosen based on their proximity to affected communities. For this study, four randomly selected sites (L1 to L4) were chosen, along with a comparison or control site (LX), which is a garden area that has no history of hydrocarbon pollution.

2.3 Methodology for Sampling

Throughout the sample process, the sites were geo-referenced using a portable Germin etrex Global Positioning System (GPS), specifically the CZ 99052-20-Taiwan model. The Kestrel NV-500 Meteorological Metre was used to do precise sampling of meteorological parameters such as temperature, relative humidity, and wind speed. Triple sampling was conducted for all sites to guarantee the utmost level of trustworthiness in the collected data. A six-level monitoring of suspended particulate matter (SPM) and meteorological indicators was conducted in six sites during the peak of the dry season. Sampling was carried out triplicate within a 10-meter radius, with the average of triplicate samples taken as the final reading. The AEROCET 531 SPM Met One meter was used for sampling.

2.4 Statistical Methodology

The statistical analysis was conducted using SPSS version 23, employing analysis of variance to determine the mean and standard deviation of the 3 replicate samples. The thoroughness of the analysis was further enhanced by the use of the Duncan Multiple Range post hoc tests, which were employed to determine the level of statistical significance ($p=0.05$) in the distribution of particulate matter and traffic count. Additionally, the 2016 iteration of Microsoft Excel was utilized to generate statistics charts, when appropriate, using average values.

3 RESULTS AND DISCUSSION

Results showed that the mean concentrations of PM1.0 particulate matter varied between 17.68 and 28.99 µg/m^3 in several locations (see Figure 1). Among the stations, L5 exhibited the greatest PM1.0 concentration, whereas L4 displayed the lowest. Notably, the control site (LX) had the lowest PM1.0 concentration in comparison to the other locations. Based on the classification criteria, PM1.0 and PM2.5 are classified as smooth or fine particulate matter (SPM) kinds. The PM1.0 values fell within the permissible threshold of 30 µg/m^3 established by the National Air Quality Standard. Nevertheless, locations L1, L2, and L4 surpassed the World Health Organization's threshold of 25 µg/m^3. These results suggest a rise in anthropogenic activities, so decision-makers should implement essential measures to decrease the levels of particulate matter in the atmosphere.

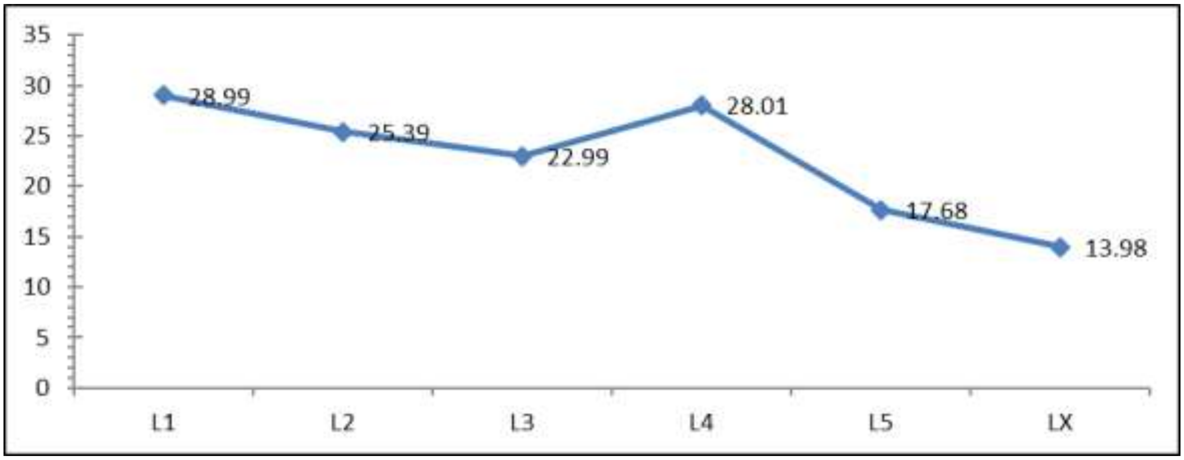

Figure 4.1: Concentrations of PM1.0 emission associated with the artisanal refining sites

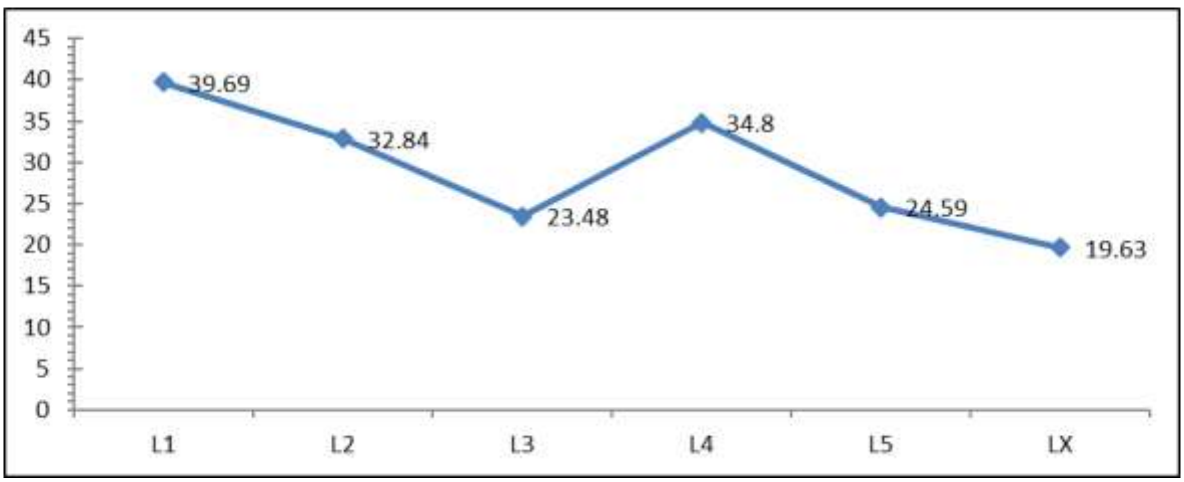

Figure 4.2: Concentrations of PM 2.5 emission associated with the artisanal refining sites

The mean SPM concentrations in the PM2.5 category are depicted in Figure 2. The study findings indicated that the PM2.5 concentration ranged from 23.48 to 39.69 µg/m^3 at the different study locations. The lowest value of 19.63 µg/m3 was monitored at the control site (LX), whereas the maximum concentration was observed at site L1. Conversely, location L3 had the lowest documented PM2.5 concentration. It should be emphasised that the PM2.5 values at sites L1, L2, and L4 are beyond the permissible limits set by the National Air Quality Standard and the WHO sites. The limits are established at 30 and 25 µg/m^3, respectively.

Furthermore, it is crucial to note that PM2.5 is a precise form of delicate particulate matter classified as a group 1 carcinogen. Thus, the existence of this substance in substantial amounts poses a grave risk to public health. Timely intervention is essential to reduce the human-induced operations of artisanal refineries to protect public health and the environment.

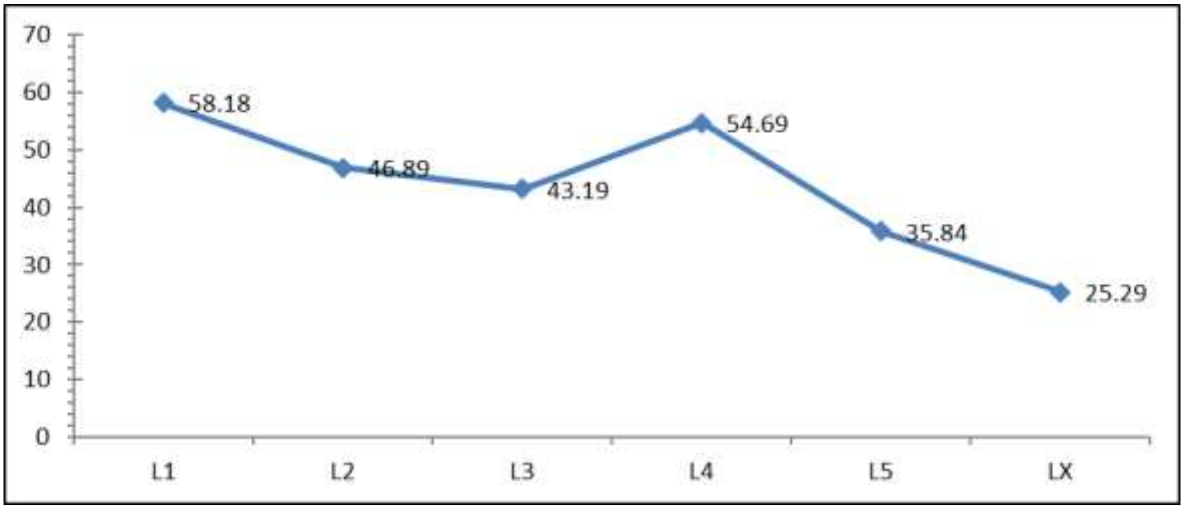

Figure 3: Concentrations of PM4.0 emission associated with the artisanal refining sites

The study examined the average atmospheric concentrations of PM4.0 particulate matter in regions linked to artisanal refining. Analysis revealed that the mean PM4.0 concentration varied between 35.84 and 58.18 µg/m3 (Figure 3). At location L5, the concentration reached its maximum value of 58.18 µg/m3, whilst the lowest concentration was recorded at site L1, measuring 35.84 µg/m3. The PM4.0 particle matter levels were consistently lowest at the control location, suggesting a substantial environmental impact resulting from artisanal refining operations. Significantly, there are no explicit regulatory thresholds for PM4.0, PM7.0, and PM10 particle matter, underscoring the necessity for policy reforms. The study concluded that it is crucial to monitor the presence of PM4.0 since it has the potential to create negative consequences. Hence, it is imperative to devise efficient strategies to decrease PM4.0 levels and safeguard the environment and human well-being.

The data shown in Figure 4 provide valuable information on the concentrations of PM7.0 particulate matter in the atmosphere, quantifying the concentration of minuscule particles that can be breathed into the respiratory system.

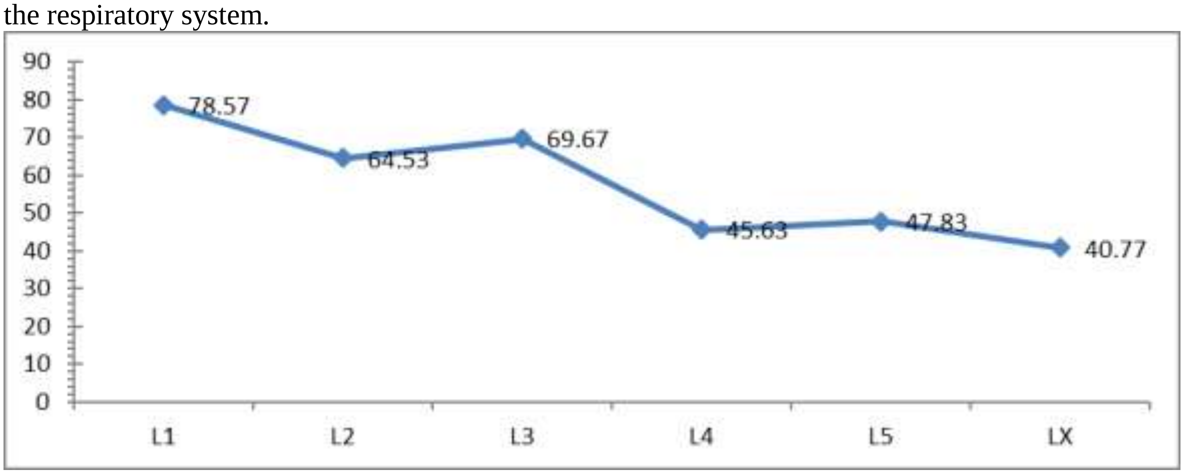

Figure 4: Concentrations of PM7.0 emission associated with the artisanal refining sites

Furthermore, the study considers the levels of PM7.0, which provides insight into the extent of human activity in the region. The study findings indicate that the PM7.0 values varied between 45.63 and 78.57 µg/m^3, suggesting a potential compromise in the air quality in the designated region. Site L1 had the greatest recorded concentration of PM7.0, whereas site L4 had the lowest PM7.0 levels. In addition, the control site had the lowest PM7.0 particulate matter concentration, measuring 40.77 µg/m^3. While there are no specific regulatory thresholds for PM7.0, the levels of this particulate matter tend to rise due to human activities, such as fine oil refining.

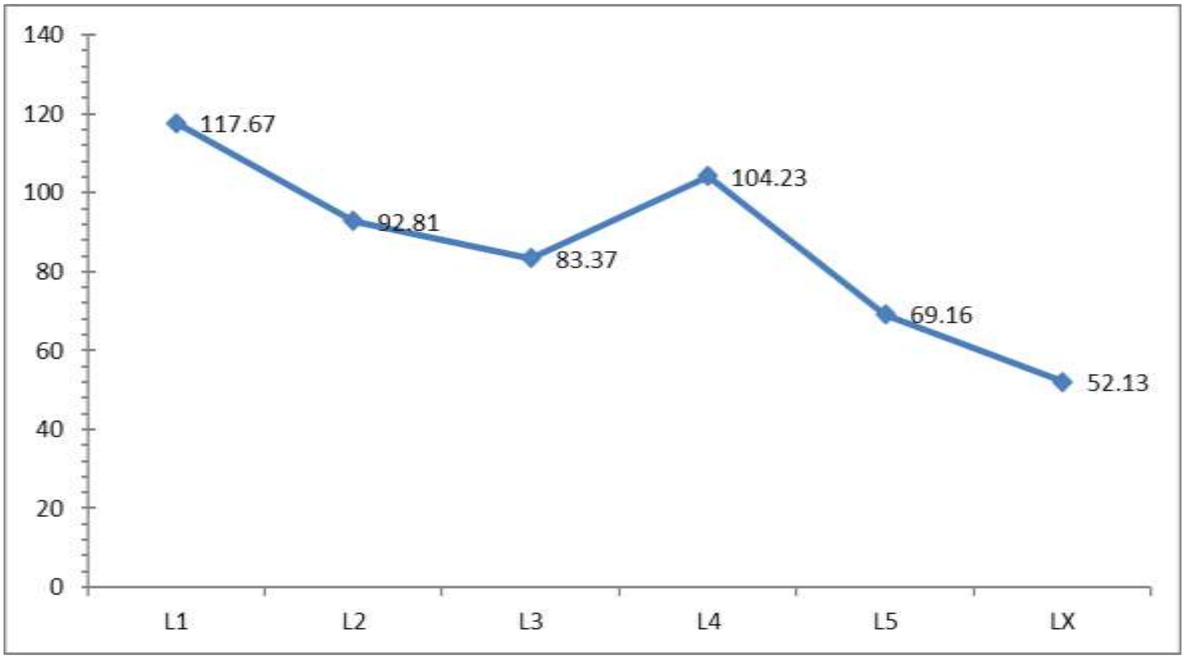

Figure 5: Concentrations of PM10 emission associated with the artisanal refining sites

The levels of PM10 particulate matter in the air at various sampling sites showed levels of PM10 ranged from 83.37 to 117.67 µg/m^3 across the different locations. (Figure 5). The site with the highest PM10 level was L1, measuring 117.67 µg/m3, while L3 had the lowest PM10 level, measuring 83.37 µg/m^3. The control site (LX) recorded the lowest PM10 level, at 52.13 µg/m^3, indicating better air quality than the other sites. Results of all the sites exceeded the recommended limit set by the World Health Organisation (WHO) of 50 µg/m^3. However, the PM10 levels recorded at all the sampling sites were still within the permissible limit compared to the national air quality limit of 100 µg/m^3. This information underscores the crucial role of each one of us in monitoring air quality levels and implementing measures to ensure they remain within safe limits to safeguard public health.

Several reports in the literature have reported that particulate matter emission has severely and negatively affected the ambient air quality in major cities around Nigeria. For instance, Oluyemi *et al.* (1994) reported that the industrial region of Lagos City had recorded total suspended particle levels ranging from 1033 to 40000 µg/m^3. PM10 levels ranging from 118.3 to 132.0 µg/m^3 were revealed in Maiduguri and Abuja in a study by Taiwo *et al*., (2014). Owoade *et al*. (2013) measured the levels of PM2.5 and PM10 in randomly selected areas of Lagos to be 27 and 69 µg/m^3, respectively, in 2013. The concentration of PM2.5 in Abuja and Aba was measured at 14 µg/m^3 and 102 µg/m^3, respectively, while the concentration of PM10 was recorded at 38 µg/m^3 and 553 µg/m^3, respectively.

The study by Obioh *et al*. (2013) found that the PM10 concentration in Abuja was 38 µg/m^3, whereas in Aba, it was a staggering 553 µg/m^3. The PM2.5 concentration ranged from 14 µg/m^3 in Abuja to 102 µg/m^3 in Aba. Ideriah *et al*. (2001) conducted a study in southeast Nigeria and found that the concentration of TSP (total suspended particles) ranged from 19.0 to 1677.9 µg/m3 in five different communities. The Total Suspended Particulate (TSP) values recorded by Ohimain et al. (2013) at a palm oil processing facility in Elele, Rivers, ranged from 1634 to 7853 g/m3. These reported PM concentrations significantly exceeded the USEPA (2008) daily and annual mean guidelines of 150 and 50 $\mu g/m^3$, respectively. Owoade *et al*. (2009) conducted a study at a steel and iron company in Lagos, which found that the concentration ranges for PM10 and PM2.5 were 86 - 8765 $\mu g/m^3$ and 10 - 462 $\mu g/m^3$, respectively. The abnormally elevated levels of these particulate matter size fractions underscore the urgent need for immediate action to protect the general population, particularly those close to the steelworks industry.

CONCLUSION

A portable digital handheld metre was used to assess the levels of suspended particle matter (SPM) and the related meteorological metrics in an artisanal crude oil refining community located in Bayelsa state. Results indicated that the majority of sites displayed substantial levels of particulate matter emissions, with certain sites surpassing the regulatory thresholds established by the National Air Quality Standards and the World Health Organisation. The distribution of particulate matter in the research region was significantly affected by meteorological variables including temperature, relative humidity, wind speed, and surface dust particles originating from the sites. As experts in the industry, your significance in executing strategies to alleviate these negative consequences is paramount.

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