PARTICULATE MATTER POLLUTION IN NIGERIA: A REVIEW

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ABSTRACT

Particulate Matter (PM) is a major air pollutant in the Nigeria atmospheric environment. This study has reviewed PM pollution in all the geopolitical zones in Nigeria. Published works relating to PM pollution in Nigerian cities were accessed and analysed. Data collected showed a high total concentration of total suspended particle (TSP) varying between 1,033 to 40,000 µg/m^3 and also a PM10 concentration range of 118.3 -132.0 µg/m3. Most of the reported PM mass concentrations in Nigeria were higher than the annual World Health Organization (WHO) standards of 90 µg/m3 for TSP and the USEPA standard of 40 µg/m^3 for PM10. In terms of apportionment, the mostly used receptor models were Principal Component Analysis (PCA) and Chemical Mass Balance (CMB). The major emission sources identified by these models were traffic, industry, soil, sea spray and biomass burning. The source apportionment study conducted in Lagos showed marine and crustal matter as the highest PM sources contributing 76% and 58% to coarse and fine PM, respectively. In the northern part of Nigeria, the major emission sources of is wind-blown dust from the Sahara desert. PM pollution is therefore a serious concern in Nigeria that required urgent mitigating measures. This may result into major health problems such as cardio-vascular and respiratory diseases as well as ill-effects on the environment.

Keywords: Particulate matter, Nigeria, health, environment, apportionment

1. Introduction

Particulate matter (PM) pollution is a serious issue of global concern. It has many negative impacts on humans, environment and atmospheric conditions including cloud formation, solar radiation, global warming, visibility and precipitation (Taiwo *et al*., 2014; Pope and Dockery 2006). Nigeria is still far behind in cut-edge researches on air pollution compared to developed nations of the world. Few works have been done on PM determination and source apportionment in Nigeria (Owoade *et al*., 2013; Efe, 2008; Koku and Osuntogun, 2007). These reported studies were based mainly on total suspended particles while few on coarse particles and PM_{10}. Studies on fine particles have been scantly reported.

Receptor models are important tools used for source identification and apportionment of particulate matter. The models use the physical and chemical characteristics of air pollutants collected at the receptor locations. Examples of receptor models are Chemical Mass Balance (CMB), Principal Component Analysis (PCA), Positive Matrix Factorization (PMF) and UNMIX. The main advantage of receptor model is to develop a mitigating strategy for PM pollution. Studies on source apportionment of PM are limited in Nigeria. Many of the published studies in Nigeria have not applied receptor model for source apportionment (e.g. Efe, 2008; Koku and Osuntogun, 2007). Oluyemi and Asubiojo (2001) using PCA and EF models have allotted the sources of PM_{10} sampled at three sampling points in Lagos. Sources identified are soil, marine, vehicular emission and regional sulphate. The main objective of this paper is to review the problems of PM pollution in Nigeria.

2. PM pollution: the Nigeria experience

Urban air quality in major Nigeria's cities has suffered PM pollution from diverse sources. For instance, Oluyemi *et al*. (1994) reported TSP concentration range of 1,033 - 40,000 µg/m^3 in Lagos (the industrial capital of Nigeria). Efe (2008) also noted PM_{10} concentration range of 118.3 µg/m^3 in Abuja to 132.0 µg/m^3 in Maiduguri (see Figure 1). The recent work of Obioh *et al*. (2013) has revealed PM_{10} concentration of 38 µg/m^3 in Abuja and 553 µg/m^3 in Aba; and $PM_{2.5}$ concentration varying between 14 µg/m^3 in Abuja and 102 µg/m^3 in Aba. Ideriah *et al*. (2001) have measured TSP concentration range of 19.0 -1677.9 µg/m^3 in five communities in south-eastern Nigeria. A study by Ohimain *et al*. (2013) at a palm oil processing industry in Elele, Rivers recorded the TSP values between 1634 and 7853 µg/m^3. These reported PM values were greater than the USEPA (2008) daily and annual mean standards of 150 and 50 µg/m^3, respectively. A study at a steel and iron industry in Lagos by Owoade *et al*. (2009) for PM_{10} and $PM_{2.5}$ revealed concentration ranges of 86 - 8765 µg/m^3 and 10 - 462 µg/m^3, respectively. The unusually high concentrations of these PM size fractions may be harmful to the public, especially the residents living around the vicinity of the steelworks industry. Recently, Owoade *et al*. (2013) have carried out PM sampling at some selected sites in Lagos; results (12-hour mean values) revealed concentrations of 27 and 69 µg/m^3 for $PM_{2.5}$ and PM_{10} respectively.

The high PM values measured at these cities may be traced directly to urbanization and population growth (Figure 1). From Figure 1, Abuja (the capital city of Nigeria) recorded the lowest PM_{10} and $PM_{2.5}$ concentrations. The Efe (2008) study has revealed the highest PM_{10} concentration in Maiduguri while the work of Obioh *et al*. (2013) in contrast, has showed Aba as the most polluted city in Nigeria. Emission sources like vehicular and industrial emissions might be responsible for high PM levels in Aba.

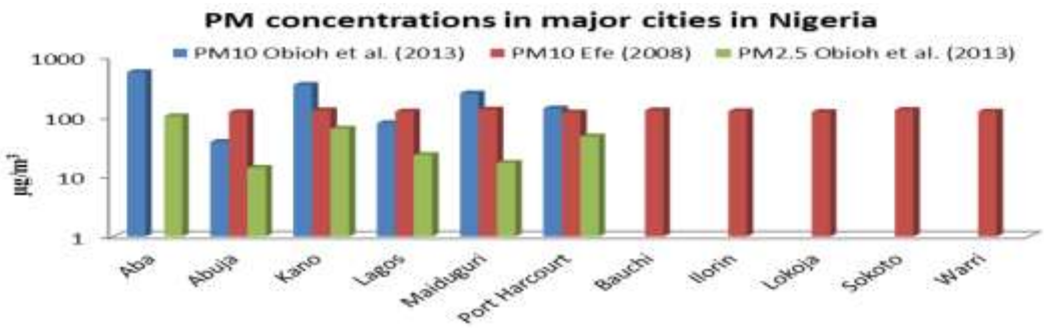

Figure 1: Average concentrations of PM_{10} measured in Nigerian cities

Harmattan is another contributor to PM mass concentrations in every part of Nigeria, but mostly pronounced in the northern part of the country (Dimari *et al*., 2008). Harmattan, according to Hastenrath (1988) is a ground level stream of dry desert air from the African continental trade wind system that sweeps from a consistent northeast direction to the south during the boreal winter. During the Harmattan period, as high as 400-1200 kg/ha dust particles are deposited in the northern part of Nigeria compared to 100-400 kg/ha in the southern part of the nation (Minka *et al*., 2014). The lowest concentrations of PM_{10} were measured in July and September, the two peaks of rainfall in Nigeria. This could have been responsible for the low PM values documented at these months. Nevertheless, PM concentrations were high throughout the year. The lowest concentration of 130 µg/m^3 reported in July and September was still higher than the reported values of PM_{10} and $PM_{2.5}$ in European countries (Querol *et al*., 2004).

Figure 2 shows the seasonal variation of PM_{10} concentrations in Nigeria. The dry season showed the greatest peak of particle pollution in Nigeria. The monthly study of PM by Efe (2008) revealed January as the highest peak of PM pollution in Nigeria because of prevalence of Harmattan dust during this period (Obioh *et al*., 2013). PM_{10} concentrations have been measured at a higher concentration at urban sites (>140 µg/m^3) than the rural sites (> 50 µg/m^3) (Efe and Efe, 2008). Studies involving PM measurement at both urban and rural settings have been scarcely reported in published literature in Nigeria.

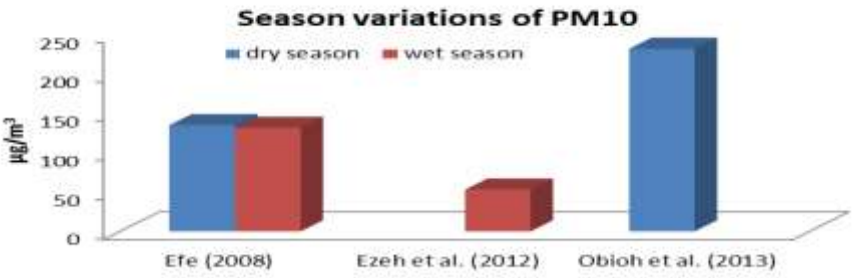

Figure 2: Seasonal variations of PM measured in Nigerian cities

3. Attaining environmental quality in Nigeria through particulate matter source apportionment

The PM sampled in Nigeria cities have been source apportioned using CMB and multivariate statistical methods (PCA and factor analysis, EF). Source apportionment using PMF and UNMIX are not common in PM studies in Nigeria. Oluyemi *et al*. (1994) have used PCA to apportion the PM samples collected at an industrial site in Lagos. In $PM_{2.5\text{-}10}$ (coarse) fraction; five factors were identified namely soil, sea-salt, industry, regional sulphate and fresh auto exhaust. Markers for soil source were Si, Ti, Al, Fe, V, K, Mg and Ca. Loadings for sea-salt were Na, Cl and Cu while for industry, tracers were Pb, Zn and Mn. Regional sulphate factor was S; while Br and Mn represented factors for fresh automobile exhaust. The application of PCA model to the fine PM portion revealed six sources namely: soil, vehicular, sea-salt, industrial 1, industrial 2 and industrial 3.

A related study by Oluyemi and Asubiojo (2001) at a site in Lagos also employed PCA for coarse PM apportionment. Five factors identified were soil, marine, traffic, 'traffic/incineration' and 'traffic/industry. Markers used for soil and marine were similar to that of Oluyemi *et al*. (1994) study. Br, Mg and Pb were tracer elements used for traffic while K, Mn, S and Pb were used traffic/incineration and Zn for 'traffic/industry'.

The chemical mass balance model was in addition to PCA employed by Oluyemi and Asubiojo (2001). Figure 3 shows the source contributions of $PM_{2.5\text{-}10}$ and $PM_{2.5}$ identified by CMB. Sources identified by CMB varied slightly from those explained by PCA. The percentages of unidentified sources were high signifying the poor performance of the model. The major PM sources from the study are soil, marine, vehicles, industry, regional sulphate, incineration and oil combustion. These sources of PM are likely to reflect emissions from Lagos metropolis, as a coastal, industrial and the only megacity in Nigeria.

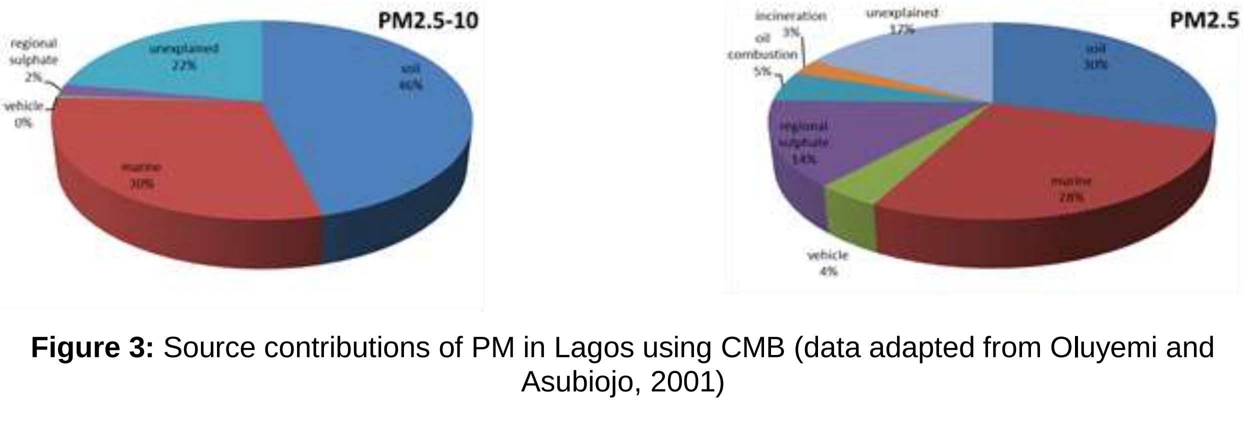

Figure 3: Source contributions of PM in Lagos using CMB (data adapted from Oluyemi and Asubiojo, 2001)

4. $PM_{2.5}/PM_{10}$ ratios in Nigeria

The ratio of $PM_{2.5}/PM_{10}$ is crucial and important to identify emission sources of PM. High ratio of $PM_{2.5}/PM_{10}$signifies domination by fine particles while low ratio value indicates domination by coarse particles. By calculating the $PM_{2.5}/PM_{10}$ for available published works in Nigeria, Obioh *et al*. (2013) revealed the value range of 0.07 at Maiduguri to 0.37 at Abuja. In Ezeh *et al*. (2012)

work in Lagos, $PM_{2.5}/PM_{10}$ ratio equals 0.12. Owoade *et al*. (2013) study in Ikoyi Lagos gives $PM_{2.5}/PM_{10}$ ratio of 0.39. The earlier study of Owoade *et al*. (2009) showed a $PM_{2.5}/PM_{10}$ value of 0.05 for particulate matter collected near a Steelworks in Nigeria. The values of $PM_{2.5}/PM_{10}$ revealed that PM size fraction in Nigeria is dominated by coarse fraction. This might be explained by pronounced emissions from soil or crustal matter and marine aerosol (in a place like Lagos and Port Harcourt). This agreed with the study of Oluyemi and Asubiojo (2001) which revealed crustal and marine particles as major contributors to air pollution in Lagos (see Figure 3).

5. Conclusion

This paper has reviewed the PM pollution in Nigeria. Different concentration ranges of PM measured in Nigerian rural and urban areas have also been highlighted. The study has portrayed the sources of PM pollution into the nation's atmospheric environment. The major sources of particles in Nigeria are soil, marine and regional aerosol.

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