

# Distribution of Particulate Matter in Cawthorne Channels Air Basin in Nigeria

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## Abstract

The concentrations of Particulate Matter (**PM**) were determined in tropical wetlands air basin of Cawthorne Channel, Awoba and Krakrama. The sampling was performed with well calibrated equipment (A MultiRAE PLUS (PGM – 50), a programmable Multi Gas monitor with an electrochemical sensor). Parameters measured were particulate matter with 1  $\mu\text{m}$ , 2.5  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ), 7  $\mu\text{m}$  ( $\text{PM}_7$ ), 10  $\mu\text{m}$  ( $\text{PM}_{10}$ ) and Total suspended particulate (TSP). Seasonal variations were displayed by all fractions of particulate matter. TSP at Cawthorne Channels was observed, with very high concentration in January ( $346.1 \mu\text{g}/\text{m}^3$ ) at the upwind and ( $401.7 \mu\text{g}/\text{m}^3$ ) downwind in dry season. This was followed by wet season measurement. The  $\text{PM}_{10}$  results at Cawthorne Channels also showed strong seasonal variations with very high concentration in January ( $313.6 \mu\text{g}/\text{m}^3$ ) at the upwind and ( $367.5 \mu\text{g}/\text{m}^3$ ) downwind. Of all the respirable particulate size fractions studied, allowable International Standard according to USEPA (1990), was exceeded in  $\text{PM}_{10}$  and  $\text{PM}_7$ .  $\text{PM}_{2.5}$  had values that were generally below  $60.0 \mu\text{g}/\text{m}^3$  while  $\text{PM}_1$  had values below  $10.0 \mu\text{g}/\text{m}^3$ . The TSP levels exceeded  $250.0 \mu\text{g}/\text{m}^3$ , being Nigerian National allowable limit. The respirable particulate matter had no statistical difference between the upwind and downwind directions ( $p < 1$ )<sub>0.05</sub>.

**Keywords:** suspended particulate matter (SPM), particulate fraction distribution, tropical wetlands and air basin

## 1. Introduction

Increase in particulate matter air contamination and their negative impacts on human health have resulted in efforts to monitor and identify the various fractions. The particulate mass concentrations in a very clean urban environment are about  $10 \mu\text{g}.\text{m}^{-3}$  (Estokova & Stevulova, 2012).

The production of atmospheric aerosols or atmospheric particulate matter by anthropogenic processes is of great concern. The effects of inhaling particulate matter have been widely studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death (Pope & Burnett, 2002). The size of the particle is a main determinant of where in the respiratory tract the particle will reside when inhaled. Larger particles are generally filtered in the nose and throat and do not necessarily cause problems, but particulate matter smaller than 10 micrometers ( $\mu\text{m}$ ), referred to as  $\text{PM}_{10}$ , can settle in the bronchi and lungs and cause health problems (Kaonga & Kgabi, 2009).

Air pollutants are sometimes classified into Suspended Particulate Matter, SPM (dusts, fumes, mists, and smokes) and gaseous pollutants (gases and vapors).

Particulate matter is the sum of all solids and liquid particles suspended in air, many of which are hazardous (Greenfacts, 2015; Estokova & Stevulova, 2012). This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets. The atmosphere contains particle sizes ranging from slightly larger than molecules up to hundreds of micrometers, which consists of a variety of chemical

compounds (Hinds, 1999; Estokova & Stevulova, 2012). Depending on their lifetime, the particulates observed at a location can be both of local origin or the product of the transport over distances of hundreds to thousands kilometers. These particles vary greatly in size, composition, and origin.

Based on size, particulate matter is often divided into two main groups (Morawska & Salthammer, 2003; USEPA, 2012; Estokova & Stevulova, 2012): The coarse fraction which contains the larger particles with a size ranging from 2.5 to 10  $\mu\text{m}$  ( $\text{PM}_{2.5-10}$ ). The fine fraction contains the smaller ones with a size up to 2.5  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ). The particles in the fine fraction which are smaller than 0.1  $\mu\text{m}$  are called ultrafine particles (Estokova & Stevulova, 2012; US EPA, 2012, Greenfacts, 2015).

Coarse Particles (CP) include all particles with an aerodynamic diameter (diameter of a sphere with unit density and mass equal to the mass of the provided particle) greater than 2.5 micrometers and less than 10 micrometers.

These particles are identified as  $\text{PM}_{2.5-10}$ .  $\text{PM}_{10}$  is an abbreviation used for so called "thoracic" particles with the diameter under 10  $\mu\text{m}$ . Fine Particles (FP) include all particles having an aerodynamic diameter less than 2.5 micrometers and greater than 0.1 micrometers ( $\text{PM}_{2.5}$ ). Ultrafine Particles (UFP) include all particles with the aerodynamic diameter of less than 0.1 micrometers (Estokova & Stevulova, 2012).

Seinfeld and Pandis (2006), reported that the 10 micrometer ( $\mu\text{m}$ ) particle size does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies. Similarly, particles smaller than 2.5 micrometers,  $\text{PM}_{2.5}$ , tend to penetrate into the gas-exchange regions of the lungs, and very small particles ( $< 100$  nanometers) may pass through the lungs to affect other organs (Kaonga & Kgabi, 2009). In particular, a study by Pope and Burnett (2002), indicated that  $\text{PM}_{2.5}$  leads to high plaque deposits in arteries, causing vascular inflammation and atherosclerosis — a hardening of the arteries that reduces elasticity, which can lead to heart attacks and other cardiovascular problems.

JOKSIĆ, *et al.* 2009, studied daily deposits of  $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$  and  $\text{PM}_1$  aerosol fractions which were collected during spring and autumn sampling periods in 2007 in Belgrade.

Comprehensive toxicological and epidemiological studies conducted over the last decades have indicated that human exposure to such small airborne particles ( $\text{PM}_{10}$  and less) have adverse health effects and may be a cause of a number of respiratory and cardiovascular inflammations (Gwinn & Vallyathan, 2006). During inhalation, the coarse particulate fraction usually remains in the upper part of the airways and lungs but the fine particles penetrate deeper and reach the alveolar region (Josic *et al.*, 2009). The chemical composition of air particulate matter fractions thus becomes very important and engrosses both scientific and public auditory (Heal *et al.*, 2005; Reiss *et al.*, 2007).

In a number of studies, investigators have observed an increased incidence of respiratory diseases in association with  $\text{PM}_{10}$  air pollution. For example, in a study conducted in the United Kingdom, an association between emergency hospital admissions for respiratory and cardiovascular disease and  $\text{PM}_{10}$  was found (Atkinson, 1999). In another study conducted in Seattle, Washington, the result demonstrated association with emergency room visits for asthmatics and  $\text{PM}_{10}$  air pollution (Schwartz, 1993). Also,  $\text{PM}_{10}$  was associated with an increase in hospital admission of the elderly for Chronic Obstructive pulmonary disease (COPD) and asthma and lower respiratory tract infections including bronchitis and pneumonia (Schwartz, 1993; Burnett, 1997; Atkinson, 1999).

Epidemiological studies have shown the relationship between  $\text{PM}_{10}$  exposure and an increase in bronchitis, chronic cough, and respiratory symptoms in persons with chronic obstructive pulmonary disease (COPD) (Abbey, *et al.*, 1995; Pope, *et al.*, 1995).

So far, studies to date have shown a dearth of information on particulate matter in the Niger delta. There is need to generate reference data to document the different size fractions of particulate matter at Cawthorne Channels, Awoba and Krakrama rural wetlands air basins. This study is different in the sense that it will characterize and document the existing levels of particulate fraction in this geographical region. This has not been done before for this area and will bridge the gap in information needs while providing a bench mark for future studies in the Niger Delta air basin. The primary objective of this study was to characterize and document particulate matter fractions in the Cawthorne Channel air basin with a view to providing baseline data for the geographical region. Cawthorne channel 2, where sampling was done, is located within Latitude 4°55'13"N and Longitude 6°00'28"E; and is located some 25 km south of Port Harcourt in Rivers State of Nigeria. Similarly, Awoba sampling site has the following co-ordinates: 4°53'16"N and 6°8'19"E. This is located at the southern bank which branches off Sombreiro River (Figure 1). Krakrama location sampling point is within the co-ordinates: 4°55'17"N and 6°9'00"E and covers a total brackish water area of 4070.5 square meters. There is a flow

station (sub-station where neighboring oil wells are pumped into a tank and re-routed into the main pipeline) at Krakrama with two horizontal flare stacks though not operational at the time of study (Figure 1).

## 2. Materials and Methods

The sampling was performed with a well calibrated equipment [MultiRAE PLUS (PGM-50)] and a programmable Multi Gas monitor with an electrochemical sensor. The parameters assessed were particulate matter of 1, 2.5, 7, 10 micron sizes ( $PM_{1-10}$ ) and Total suspended particulate (TSP). These were monitored 1.5 meters above ground level for five months in 2012.

## 3. Results and Discussions

### $PM_{10}$

The  $PM_{10}$  results at Cawthorne Channels ranged from 313.6 upwind to 367.5  $\mu g/m^3$  downwind with a mean of  $340.55 \pm 38.11 \mu g/m^3$  in January, dry season. The wet season data ranged from 10.3 - 160.0  $\mu g/m^3$ , with a mean of  $91.23 \pm 77.3 \mu g/m^3$  upwind and 10.5 - 180.2  $\mu g/m^3$ , with a mean of  $101.43 \pm 85.4 \mu g/m^3$  downwind. The result showed strong seasonal variations with very high concentration in January (313.6  $\mu g/m^3$ ) at upwind and 367.5  $\mu g/m^3$  downwind (Figure 2). The wet season data constituted the lowest data, especially in the month of September when the lowest value of 10.3  $\mu g/m^3$  was obtained. In contrast, the highest PM 10 value was obtained in the month of January (Figure 2).



Figure 1. Map of Niger Delta (Nigeria) showing sampling stations

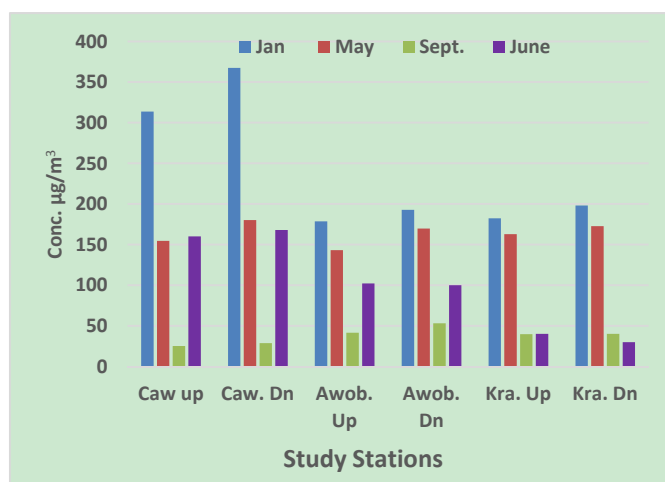


Figure 2. PM<sub>10</sub> levels in wetlands air basin in Jan – June

Similarly, PM<sub>10</sub> distribution from Awoba ranged from 178.5–192.8 µg/m<sup>3</sup> with a mean of 185.65±10.1 µg/m<sup>3</sup> in January, dry season. The wet season distribution ranged from 16.9 – 143.2 µg/m<sup>3</sup> with a mean of 82.05± 53.7 µg/m<sup>3</sup> upwind and 34.3–169.7 µg/m<sup>3</sup> with a mean of 94.0±57.2 µg/m<sup>3</sup> downwind. Similarly, PM 10 at Krakrama ranged from 182.4 to 198.1 µg/m<sup>3</sup> with a mean of 190.25 ± 11.10 µg/m<sup>3</sup> in January, dry season. The wet season data ranged from 39.8 to 162.8 µg/m<sup>3</sup> with a mean of 80.9±70.9 µg/m<sup>3</sup> upwind, whereas it ranged from 30.0 to 172.6 µg/m<sup>3</sup>, with a mean of 80.9±79.6 µg/m<sup>3</sup> downwind.

There was no statistical difference between data from upwind and downwind locations at Krakrama as ( $p \leq 1$ )<sub>.05</sub>. Wet season values were generally lower than the dry data, with the lowest data being obtained from the month of September throughout all stations. Conversely, the dry season month, January had the highest data which exceeded international levels (Figure 2).

### PM<sub>7</sub>

PM<sub>7</sub> concentration at Cawthorne Channels, ranged from 266.7 µg/m<sup>3</sup> at the upwind to 297.0 µg/m<sup>3</sup> downwind, with a mean of 281.85±21.4 µg/m<sup>3</sup> in January, being dry season (Figure 3). Similarly, the wet season data ranged from 9.4 µg/m<sup>3</sup> to 112.7 µg/m<sup>3</sup>, with a mean of 61.05 ±73.04 µg/m<sup>3</sup> upwind; whereas, at downwind, PM 7 ranged from 9.3 to 115.0 µg/m<sup>3</sup> with a mean of 62.15 µg/m<sup>3</sup>. PM<sub>7</sub>, like others, displayed high seasonality but there was no significant difference between upwind and downwind. Similarly, in January being dry season, PM 7 at Awoba ranged from 110.0 at upwind to 165.0 µg/m<sup>3</sup> downwind, with a mean of 137.5±38.9 µg/m<sup>3</sup>. In the wet season, PM 7 ranged from 10.2–98.2 µg/m<sup>3</sup>, with a mean of 54.2 µg/m<sup>3</sup> upwind and 10.8– 124.8 µg/m<sup>3</sup>, with a mean of 67.8 µg/m<sup>3</sup> downwind. September was the month with the lowest value while January had the highest concentration.

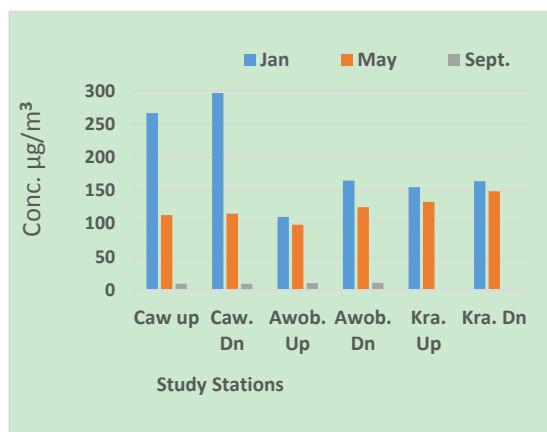


Figure 3. PM<sub>7</sub> levels in wetlands air basin in Jan – June

At Krakrama station, PM 7 ranged from 155.0 – 164.0  $\mu\text{g}/\text{m}^3$  with a mean of  $159.5 \pm 6.4 \mu\text{g}/\text{m}^3$  in January; while in wet season, a range of 132.8-148.7  $\mu\text{g}/\text{m}^3$  was observed, with a mean of  $140.8 \pm 11.2 \mu\text{g}/\text{m}^3$  (Figure 3). At Krakrama, like other stations, the lowest data was recorded in September while the highest was observed in January.

### PM<sub>2.5</sub>

PM<sub>2.5</sub> concentrations in January at Cawthorne Channels ranged from 48.9  $\mu\text{g}/\text{m}^3$  to 59.7  $\mu\text{g}/\text{m}^3$  in the dry season, with a mean of  $54.3 \pm 7.6 \mu\text{g}/\text{m}^3$  (Figure 4); while in the wet season, it ranged from 2.2 to 40.9  $\mu\text{g}/\text{m}^3$ , with a mean of  $21.55 \pm 27.4 \mu\text{g}/\text{m}^3$  upwind and 2.2 to 46.3  $\mu\text{g}/\text{m}^3$ , with a mean of  $24.25 \pm 31.2 \mu\text{g}/\text{m}^3$  downwind.

PM<sub>2.5</sub> data from Awoba ranged from 41.1-43.2  $\mu\text{g}/\text{m}^3$  in January, dry season. In wet season, PM 2.5 ranged from 8.9–36.4  $\mu\text{g}/\text{m}^3$ , with a mean of  $22.7 \pm 19.5 \mu\text{g}/\text{m}^3$  upwind and 9.3 to 41.2  $\mu\text{g}/\text{m}^3$ , with a mean of  $25.3 \pm 22.6 \mu\text{g}/\text{m}^3$  downwind. There was no statistical difference between the up and downwind locations at Awoba ( $p < 1$ )<sub>0.05</sub>. The month with the lowest data was September while January had the highest data.

At Krakrama in January, PM<sub>2.5</sub> concentrations ranged from 42.7 – 48.2  $\mu\text{g}/\text{m}^3$  with a mean of  $45.5 \pm 3.9 \mu\text{g}/\text{m}^3$ . In the wet season, PM 2.5 ranged from 32.5 – 40.6  $\mu\text{g}/\text{m}^3$  (Figure 4).

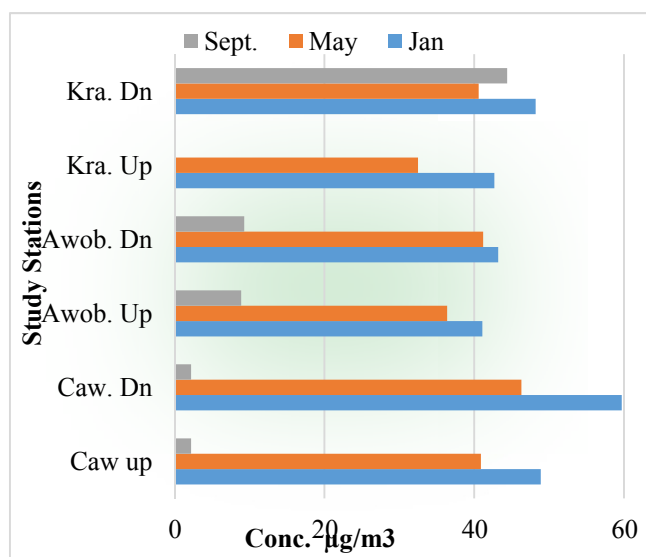
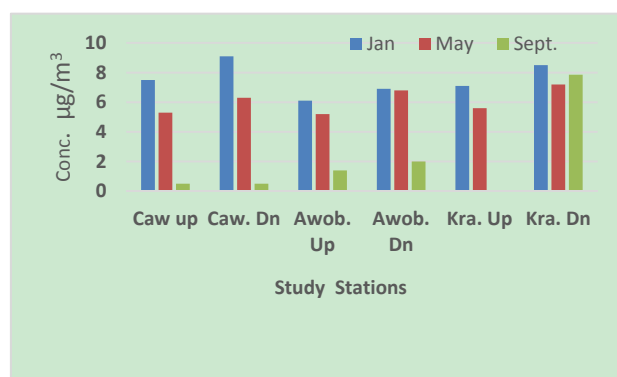


Figure 4. PM<sub>2.5</sub> levels in wetlands air basin in Jan. – June

### PM<sub>1</sub>

PM 1 concentrations at Cawthorne Channels ranged from 7.5 to 9.1  $\mu\text{g}/\text{m}^3$  in January, with a mean of  $8.3 \pm 1.1 \mu\text{g}/\text{m}^3$ ; while in wet season, PM 1 ranged from 0.5 -6.3  $\mu\text{g}/\text{m}^3$  with a mean of  $2.9 \pm 3.4 \mu\text{g}/\text{m}^3$  (Figure 5). Data from Awoba ranged from 6.1-6.9  $\mu\text{g}/\text{m}^3$  in January, with a mean of  $6.5 \pm 0.6 \mu\text{g}/\text{m}^3$ ; while the wet season PM 1 ranged from 1.4 –6.8  $\mu\text{g}/\text{m}^3$ , with a mean of  $3.85 \pm 2.6 \mu\text{g}/\text{m}^3$  (Figure 5).

At Krakrama, PM 1 ranged from 7.1-8.5  $\mu\text{g}/\text{m}^3$  in January, with a mean of  $7.8 \pm 1.0$ . In wet season, PM 1 ranged from 5.6–7.2  $\mu\text{g}/\text{m}^3$ , with a mean of  $6.4 \pm 1.1 \mu\text{g}/\text{m}^3$ .

Figure 5. PM<sub>1</sub> levels in wetlands air basin in Jan. – Sept

### TSP

Total suspended particulate concentrations at Cawthorne Channels ranged from 346.1 to 401.7  $\mu\text{g}/\text{m}^3$  in January, with a mean of  $373.9 \pm 39.3 \mu\text{g}/\text{m}^3$  (Figure 6). Similarly, the wet season data ranged from 10.4  $\mu\text{g}/\text{m}^3$  upwind to 215.2  $\mu\text{g}/\text{m}^3$ , with a mean of  $112.6 \mu\text{g}/\text{m}^3$ . January was the month with highest data while September was the month with lowest data. TSP data from Awoba ranged from 198–200.0  $\mu\text{g}/\text{m}^3$ , with a mean of  $199 \pm 1.3 \mu\text{g}/\text{m}^3$  in January. Conversely, the wet season data ranged from 34.8 – 193.4  $\mu\text{g}/\text{m}^3$  with a mean of  $114.3 \pm 83.0 \mu\text{g}/\text{m}^3$ . Like other stations, September had the lowest value while January had the highest data.

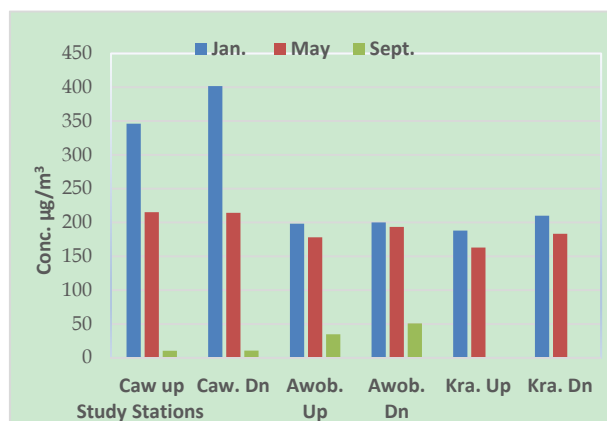


Figure 6. TSP levels at wetland air basin in Jan. and Sept

At Krakrama, TSP ranged from 188.0–210.0  $\mu\text{g}/\text{m}^3$  in January, with a mean of  $199.7 \pm 15.6 \mu\text{g}/\text{m}^3$ . In wet season, TSP ranged from 162.9 – 183.4  $\mu\text{g}/\text{m}^3$ , with a mean of  $173.2 \pm 14.5 \mu\text{g}/\text{m}^3$ . Of all stations studied, Cawthorne Channels had the highest data in all fractions followed by krakrama (Figures 2–6).

### 4. Discussion

The observed PM 10 concentrations were higher than International allowable limit of  $150.0 \mu\text{g}/\text{m}^3$  (WHO, 2005) in the dry season. This may be attributed to the hamattan season, which is dust laden and also gas flaring operations. Gas flaring involves the combustion of natural gas in a controlled manner. This combustion process produces particulate matter of various fractions in addition to some gases.

Low values in wet season months (May, June and September) are due to the scavenging mechanism of precipitation (USEPA, 1990). USEPA reports that rainfall washes particulate away from the atmosphere thereby leading to particulate reduction. Among all the meteorological parameters, precipitation has been shown to have the greatest influence on particulate air quality. Rainfall has the effect of reducing re-entrainment of particle and washing them out of the air (USEPA, 1990). However, variations in downwind and upwind were not remarkable.

### PM 7

Levels of PM<sub>7</sub> above  $150.0 \mu\text{g}/\text{m}^3$  occurred at all stations. The reasons for these increases may be due to the gas

flaring emissions and hamattan effect. Low results obtained in wet season months (May and September) are attributed to precipitation effects. International allowable limits were exceeded at all sites except one, Awoba.

### PM<sub>2.5</sub> and PM<sub>1</sub>

PM<sub>2.5</sub> and PM<sub>1</sub> had values that were lower than the international allowable limit of 65.0 µg/m<sup>3</sup> (WHO, 2005). The result also showed that much of the particulate in the air was in the coarse fraction of particle size of 10 microns (PM<sub>10</sub>) and 7 microns (PM<sub>7</sub>). Of all the size fractions studied, allowable International Standard according to USEPA (1990), was exceeded in PM<sub>10</sub> and PM<sub>7</sub>. PM<sub>2.5</sub> had values that were generally below 60.0 µg/m<sup>3</sup> while PM<sub>1</sub> had values below 10.0 µg/m<sup>3</sup> (Figures. 4 & 5). These are the fine fractions that can be inhaled into the alveoli and bronchioles of the lungs.

### TSP

Total Suspended Particulate Matter (SPM) for Krakrama and Awoba were within the same range (188.0 – 210.0 µg/m<sup>3</sup>) and much below the Nigerian National Standard of 250.0 µg/m<sup>3</sup> (Figure 6). The ambient Total Suspended Particulate Matter (TSP) reaching 401.7 µg/m<sup>3</sup> and observed in January, shows impact of hamattan season.

Of all the size fractions studied, the allowable International Standard according to USEPA (1990), was exceeded in PM<sub>10</sub> and PM<sub>7</sub>. PM<sub>2.5</sub> had values that were generally below 60 µg/m<sup>3</sup> while PM<sub>1</sub> had values below 10.0 µg/m<sup>3</sup>. As would be expected, there was a gradual decrease in particulate concentrations of lower sizes in this order: PM<sub>10</sub> > PM<sub>7</sub> > PM<sub>2.5</sub> > PM<sub>1</sub>. Particulate sizes and very low wet season (September) data were common at all air basins and size fractions.

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