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Resipirable Particulate Matter Monitoring And Audit Over Athi River Township, Kenya

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***Abstract*—Air pollution is a concern in both developing and developed countries where industrialization is on the rise. With increased industrialization, emission levels increase, raising pollution levels resulting into environmental and health concerns thus the need to keep the pollution levels under control. This research presents a statistical analysis of the particulate matter (PM) over Athi River town in Kajiado County, Kenya which is predominated with cement producing industries. The data was collected over three sites downwind of the town that are highly exposed to these PM from the town. The BAM 1020 air sampler was used to measure the PM levels. Site 1 (East Africa Portland Cement), which is a factory within the industrial area, had 81.75 µg/m^3 for PM2.5 and 161.875 µg/m^3 for PM10 while Sites 2 (Standard Gauge Railway Athi River Station) and 3 (Athi River GK Prisons), which are within the residential area, had 33.273 µg/m^3 for PM2.5 and 67.812 µg/m^3 for PM10, and 32.093 µg/m^3 for PM2.5 and 68.5 µg/m^3 for PM10 respectively. The particulate matter concentrations were generally high compared to the World Health Organisation (WHO) and National Environment Management Authority (NEMA) air quality limits; permissible limits for PM2.5 and PM10 for 24 hour duration at Industrial areas are 75 µg/m^3 and 150 µg/m^3 respectively while residential areas are 25 µg/m^3 and 50 µg/m^3 respectively. There are costs related to lost man-hours and undocumented effects on health which affects the productivity of the industries. Therefore, there is need to improve air Quality in Athi River through designing of industrial dust control systems, regular environmental audit and monitoring practices by the industries and enhanced enforcement by sector regulators (NEMA and Directorate of Occupational Safety and Health Services (DOSHS)) to ensure compliance by all participants.**

Keywords—Air Quality; Particulate Matter; Pollution; Athi River

I. INTRODUCTION

Many regions of the world are affected by Poor air quality. Low income cities, however, are the most hit by this phenomenon. 97% of all cities in low and middle income countries, as per the air quality database, whose populations are over 100,000 inhabitants do not meet World Health Organization (WHO) air quality guidelines [1]. In a year, an estimated 4.2 million deaths occur as a result of ambient air pollution which brings about stroke, lung cancer, heart and chronic and acute respiratory diseases. Around 91% of the world's population lives in places where air quality levels exceed WHO limits [2]. Outdoor and household air pollution also cause approximately 7 million premature deaths each year. It is also noted that more than 80% of urban dwellers are exposed to air pollution levels in excess of the WHO permissible limits [3].

Some researchers have shown that particulate matter (PM), especially PM2.5, affects more people than any other pollutant [4]. There is a direct link between sizes of particles and the health problems they pose. However, smaller particles of diameters 10 micrometers and less are the main drivers of these problems. They easily gain access to the lungs and even into the bloodstream. Proven scientific studies have shown that exposure to these particle pollution leads into nonfatal heart attacks, irregular heartbeat, premature death in people with heart or lung disease, decreased lung function, aggravated asthma and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. Other effects are reduced visibility, environmental damage, such as damaging sensitive forests and farm crops, making lakes and streams acidic, depleting the nutrients in soil, affecting the diversity of ecosystems, contributing to effects of acid rain and changing the nutrient balance in coastal waters and large river basins, and material damage such as stone and other materials, including culturally important objects such as statues and monuments [5]. Other researchers have also shown that for every 10 µg/m^3 increase in PM2.5, mortality increases by between 3-26%, chances of childhood asthma increase by 16%, chances of lung cancer increase by 36% and heart attacks increase by 44%. Exposure, on a daily basis, to air pollution of 22 µg/m^3 is equivalent to smoking 1 cigarette according to Berkeley Earth report [6].

In Kenya, pollution levels are kept under check by some laws presented in various statutes. Every person in Kenya has a right to a clean and healthy environment, according to the Constitution of Kenya, Article 42, Chapter 4, the Bill of Rights [7]. It,

therefore, becomes important, owing to the adverse effects posed by the PM, to keep check on the levels of the particulate matter (PM) in the air, especially in areas which are highly populated. It is against this background that this research embarked on an environmental audit in Athi River town with an aim of determining the concentration levels of PM in the air.

This research thus sought to monitor and document ambient PM levels by taking representative samples of the PM from three different sites in Athi River Township.

II. MATERIALS AND METHODS

A. Monitoring Sites

The study area is Athi River Township (global positioning system (gps) coordinates of 1° 27' 27.81'' S and 36° 58' 42.6108'' E, elevation is 1532 m). Athi River Town is located in Kajiado County, about 20km southeast of Nairobi County, on the shores of the quasi-periodic Athi River. The surrounding area of the town is officially designated as an industrial zone with many large-scale commercial activities ranging from incinerators, long haul transport, cement production, manufacturing, industrial services, salt production, steelworks and quarrying, and many more. There are seven cement factories located within the town: East Africa Portland Cement Company, Mombasa Cement, Bamburi Cement, Ndovu Cement, Savannah Cement, National Cement and Athi River Mining.

Air pollution from industrial activities is a major problem in Athi River. To address this issue, it was however necessary to confirm the levels of the air pollutants in the air especially the PM10 and PM2.5

This study, therefore, sought to monitor and document ambient PM levels by taking representative samples of PM10 and PM2.5 from three different sites. These sites were selected putting into consideration the wind direction that might influence their exposure, locations of the existing industries and the security of the monitoring equipment. These sites are: East Africa Portland Cement, Standard Gauge Railway Athi River Station and Athi River Government of Kenya (GK) Prisons as shown in the table 1 and fig. 1 below.

TABLE 1: LOCATION OF THE MONITORING SITES

Site	Name	Latitude	Longitude	Description
1.	East Africa Portland Cement	1º 27.115’ S	36º 57.437’ E	One of the major cement factories in Athi River
2.	Standard Gauge Railway Athi River Station	1º 28.054’ S	36º 59.246’ E	Located downwind of the major factories and to the south east of Athi River
3.	Athi River GK Prisons	1º 28.387’ S	36º 56.387’ E	Located downwind of the major cement factories and to the south west of Athi River

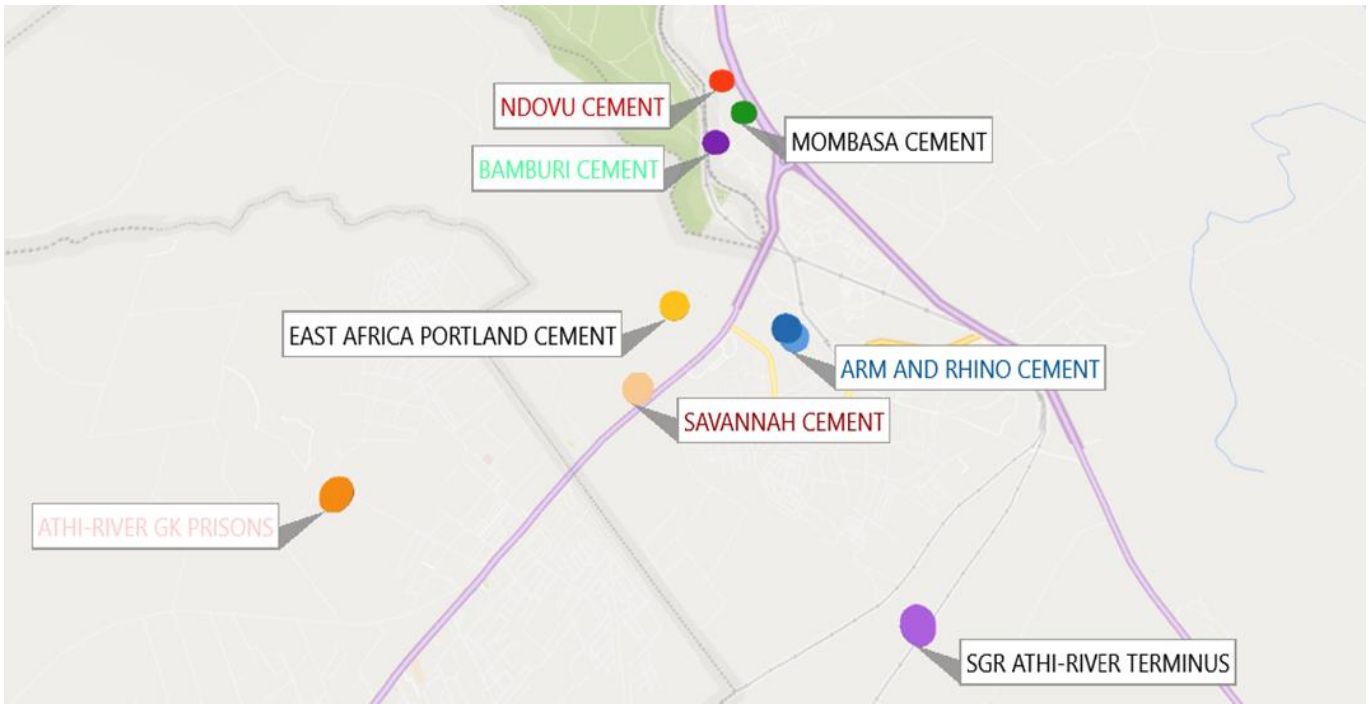

Fig. 1 Map showing location of Sampling Sites

B. Sampling Method

The BAM 1020 air sampler was used to measure the levels of PM10 and PM2.5 in the air. It automatically measures and records airborne particulate matter (PM) concentration levels in $\mu g/m^3$ at local conditions of temperature and atmospheric pressure using the principle of beta ray attenuation. At the beginning of each sample hour, a small carbon-14 (14C) element emits a constant source of high-energy electrons known as beta rays through a spot of clean glass fiber filter tape. These beta rays are detected and counted by a sensitive scintillation detector to determine a zero reading. The equipment then advances this spot of tape to the sample nozzle, where a vacuum pump pulls a measured and controlled amount of PM laden air through the tape. Once per hour, after the filter tape has collected some amount of ambient particulate matter (PM), it is automatically placed between the source and the detector thereby causing an attenuation of the beta ray signal. The degree of attenuation of the beta ray is used to determine the mass concentration of particulate matter (PM) in the ambient air.

Fig 3.5 BAM 1020

III. RESULTS AND DISCUSSION

Three sites were selected, as representatives of Athi River, for data collection in order to determine the particulate matter (PM) concentration in Athi River. The table below shows the data obtained using the BAM 1020 air sampler.

TABLE 2: SUMMARIZED VALUES OF PM2.5 AND PM10 AT ATHI RIVER

	SITE 1 (East Africa Portland Cement)		SITE 2 (Standard Gauge Railway Athi River Station)		SITE 3 (Athi River GK Prisons)	
	PM2.5 (µg/m^3)	PM10 (µg/m^3)	PM2.5 (µg/m^3)	PM10 (µg/m^3)	PM2.5 (µg/m^3)	PM10 (µg/m^3)
24hr mean	81.75	161.875	33.273	67.812	32.093	68.5
Max value	170	490	80	400	68	390
Min value	45	70	20	30	20	30
Day mean	62.667	128.75	26.833	57.5	28.385	61.5
Night mean	100.833	199.167	41	77.89	35.8	74.9
WHO 24hr AQG	75	150	25	50	25	50

The table 2 above shows, in summary, the 24hr means, Maximum values, Minimum Values, Day means, Night means observed at the three sites and also shows the internationally accepted limits as presented by WHO 24hr AQG values. Records obtained from WHO 2005 Air Quality Guideline (AQG) and National Environment Management Authority (NEMA) indicate that the permissible levels for PM2.5 and PM10 for 24 hour duration at Industrial areas are 75 µg/m^3 and 150 µg/m^3 respectively and those for Residential areas are 25 µg/m^3 and 50 µg/m^3 respectively. The guidelines limits are aimed at achieving the lowest concentrations of particulate matter (PM) possible since small particulate pollution have health impacts even at very low concentrations. Table 4.1 above shows that the mean 24 hours WHO AQG and NEMA have been exceeded for both PM2.5 and PM10 at all the observational sites.

The general data as obtained from these sites are as shown in the graphs below:

A. Site 1 (East Africa Portland Cement)

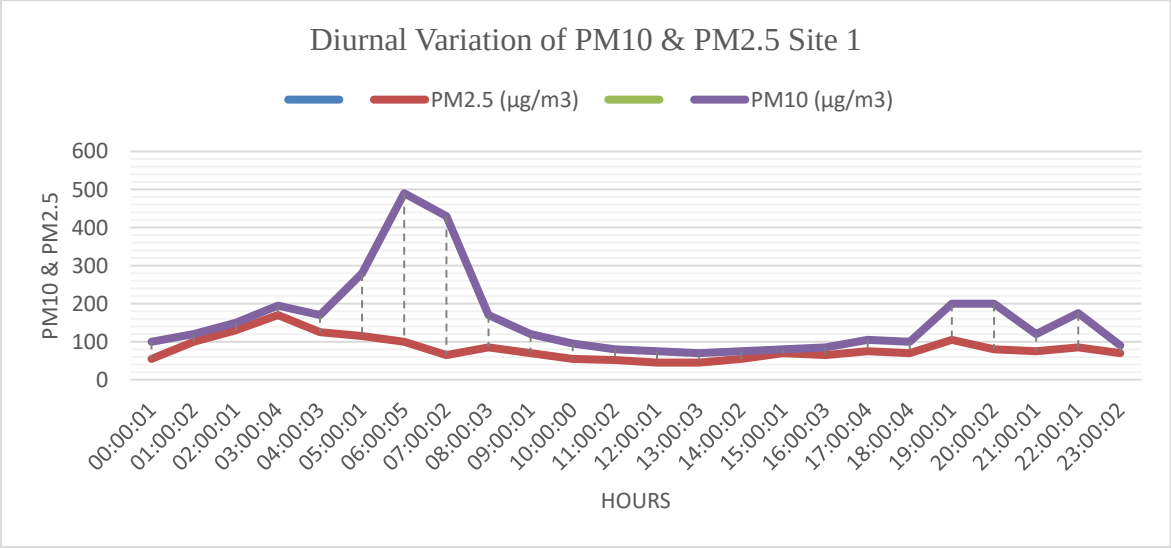

Fig 2. Diurnal Variation of PM10 and PM2.5 in Site 1

East Africa Portland Cement is one of the major cement manufacturing companies in Athi River. From fig. 2 above it is shown that the concentrations are higher in early morning and late evening. Table 2 shows the 24hr mean in this area as 81.75 µg/m^3 for PM2.5 and 161.875 µg/m^3 for PM10. According to WHO 2005 Air Quality Guideline (AQG) and National Environment Management Authority (NEMA), the permissible levels for PM2.5 and PM10 for 24 hour duration at Industrial areas are 75 µg/m^3 and 150 µg/m^3 respectively and therefore it is evident that the levels of PM obtained at this area are beyond the permissible limit

B. Site 2 (Standard Gauge Railway Athi River Station)

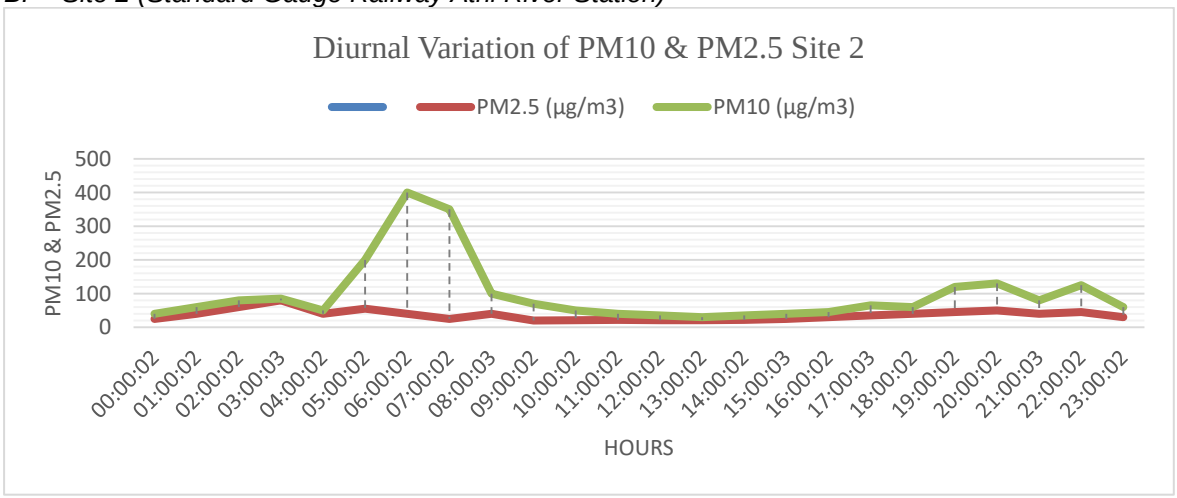

Fig 3. Diurnal Variation of PM10 and PM2.5 in Site 2

Standard Gauge Railway Athi River Station is located downwind of the major cement and other factories and to the south east of Athi River town. From fig. 3 above it is observed that the PM concentrations are higher in early morning and late in the evening. Table 2 shows the 24hr mean in this area as 33.273 µg/m^3 for PM2.5 and 67.812 µg/m^3 for PM10. According to WHO 2005 Air Quality Guideline (AQG) and National Environment Management Authority (NEMA), the permissible levels for PM2.5 and PM10 for 24 hour duration at Residential areas are 25 µg/m^3 and 50 µg/m^3 respectively and therefore it is evident that the levels of PM obtained at this area are beyond the permissible limits.

C. Site 3 (Athi River GK Prisons)

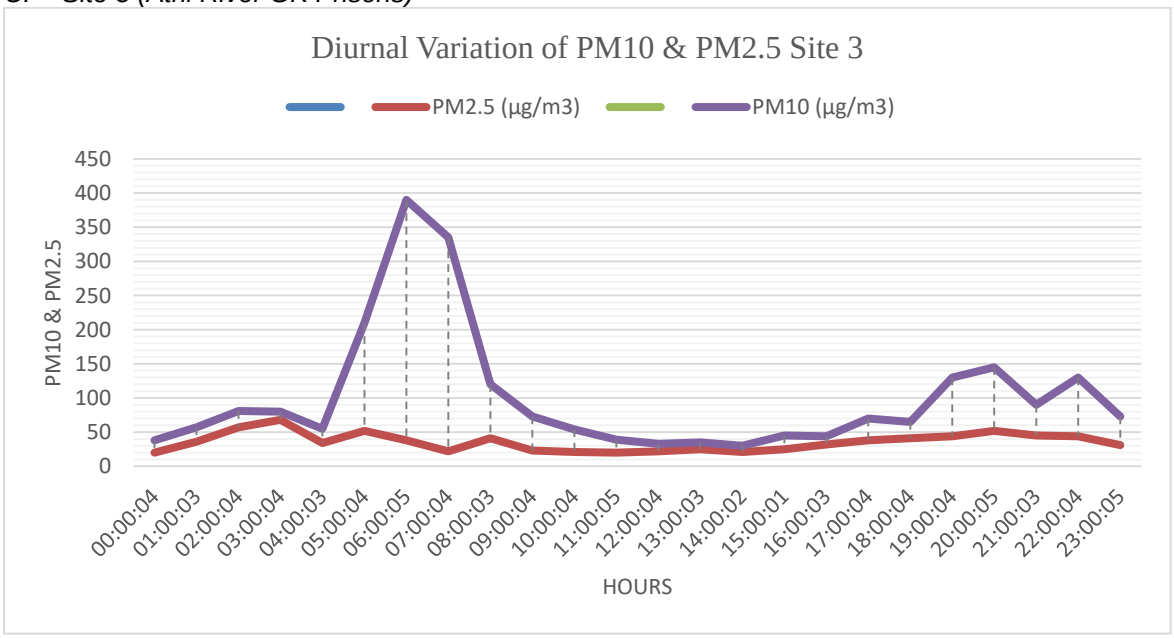

Fig 4. Diurnal Variation of PM10 and PM2.5 in Site 3

Athi River Government of Kenya Prisons is located downwind of the major cement and other factories and to the south west of Athi River town. From fig. 4 above it is observed that the PM concentrations are higher in early morning and late in the evening. Table 2 shows the 24hr mean in this area as 32.093 µg/m^3 for PM2.5 and 68.5 µg/m^3 for PM10. According to WHO 2005 Air Quality Guideline (AQG) and National Environment Management Authority (NEMA), the permissible levels for PM2.5 and PM10 for 24 hour duration at Residential areas are 25 µg/m^3 and 50 µg/m^3 respectively and therefore it is evident that the levels of PM obtained at this area are beyond the permissible limits.

From the figures above in general, it is observed that the concentrations of both PM10 and PM2.5 are higher in the night than during the day and especially in early morning and early in the night. This may be attributed to the low temperatures and wind speeds observed during these times causing low dispersion

rates leading to higher concentrations of these pollutants at around ground level.

IV. CONCLUSION AND RECOMMENDATION

The study revealed that the concentration of the particulate matter (PM10 and PM2.5) were above the local and WHO permissible limits for both Industrial and Residential areas in Athi River. To improve air Quality in Athi River, industrial dust control systems are required, regular environmental audit and monitoring practices encouraged and sector regulators (NEMA and Directorate of Occupational Safety and Health Services (DOSHS)) should enhance enforcement and ensure compliance by all participants.

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