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# Dependence of Air Quality on Meteorological Parameters in Dar es Salaam, Tanzania

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***ABSTRACT***

*The influence of meteorology on air quality in Dar es Salaam was investigated. Precipitation, temperature, relative humidity and wind speed were measured during wet and dry seasons of 2005 and 2006 period and their relationship with reported mass of particles of aerodynamic diameter smaller than 10 µm (PM10) for the site was assessed. Results indicate that the highest median concentrations for the PM10 mass (58 µg/m$^3$) was observed during the 2005 dry season and the lowest median (40 µg/m$^3$) during the 2006 wet season. It is interpreted that reasons for the higher levels of the PM10 mass in the dry season are due to temperature inversions, soil dust dispersal and absence of rain wash-down. The observed PM10 levels are also affected by the variations in sources strengths and in meteorological conditions such as mixing height, precipitation, relative humidity, wind speed and direction as supported by air mass trajectories.*

**Keywords**: PM10, Meteorology, Seasons variation, Air Mass Trajectory

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## INTRODUCTION

Particles of aerodynamic diameter smaller than 10 µm (PM10) and those smaller than 2.5 µm (PM2.5), have been found to be associated with human health problems (Dockery and Pope, 1996; Pope, 2000) and ambient air quality problems, such as visibility reduction (Watson, 2002). Atmospheric particles of submicrometer-sized are also reported by IPCC (2007) to firstly affect the Earth's climate in two ways; firstly, by scattering and absorbing incoming solar radiation and outgoing terrestrial infrared radiation and secondly by influencing properties and formation processes of clouds (ability to act as cloud condensation nuclei and ice nuclei). In this way, aerosols can affect the concentration and size distribution of cloud droplets. More effects have been associated with ability to alter cloud radiative properties, cloud lifetime, the nature and allocation of rain clouds resulting to interferences with the hydrological cycle (Toon, 2000). In addition, aerosol particles influence many atmospheric processes and acidification of clouds (Khoder, 2002) and impacts on climate and ecosystems.

Abundances and chemical compositions of aerosols differ due to physical processes and their origin. These also influence sizes and their spatial and temporal variability. It is apparent that urban areas differ from rural areas due to differences in physical obstacle characteristics that affect aerosol movements. In Tanzania and particularly in Dar es Salaam, very limited aerosol measurements and their relation to climatic parameters are available (Koleleni, 2002; Johnson et al., 2004; 2010 Mkoma et al., 2009a,b; Mkoma el at., 2010). The aim of this study was to address the dependence of air quality on meteorological parameters in Dar es Salaam to better understand the pollution levels of the city.

## MATERIALS AND METHODS

Meteorological parameters were collected between May 2005 and May 2006 at the Tanzania Meteorological Agency (TMA) synoptic station located at Dar es Salaam International Airport and at Dar es Salaam Harbour (Port). Dar es Salaam city is the economical capital of Tanzania with a population of around 4 million (Estimate, 2009) located in the eastern part of Tanzania at the Indian Ocean. The influence of meteorological processes on aerosol samples collected 2 km and 10 km from the meteorological stations was done and the detail description for the study site can be found elsewhere (Mkoma et al., 2009a,b and Mkoma et al., 2010).

## RESULTS AND DISCUSSION

### Local Meteorology

The temporal and spatial variability of the atmospheric particles and its components are influenced by meteorological parameters such as rainfall, temperature, relative humidity, and air flow patterns

(Bardouki et al., 2003). Despite its proximity to the equator, Dar es Salaam enjoys a pleasant warm climate. The annual mean temperature is 26 °C ranging from 22 to 31 °C (annual mean minimum and maximum temperature, respectively) based on a 33-year period of 1971-2003. From July to September are the driest months. The annual average relative humidity is 96% in the morning and 67% in the afternoon. The main rainy season, which occurs between March and May, is responsible for 80% of the annual average rainfall of 1100 mm in Dar es Salaam. Figure 1 shows the results for relative humidity and rainfall for all days of the 2005 and 2006 because the air quality of a site is highly influenced by the relative humidity and rainfall of the days before any measurement of pollutants is done. It can be seen from Fig. 1 that a seasonal cycle of rainfall and relative humidity was observed for Dar es Salaam as can also be observed in years 1971-2003 (Fig. 2). The average values for temperature and wind speed are presented only for the days were measurements performed (Fig. 3).

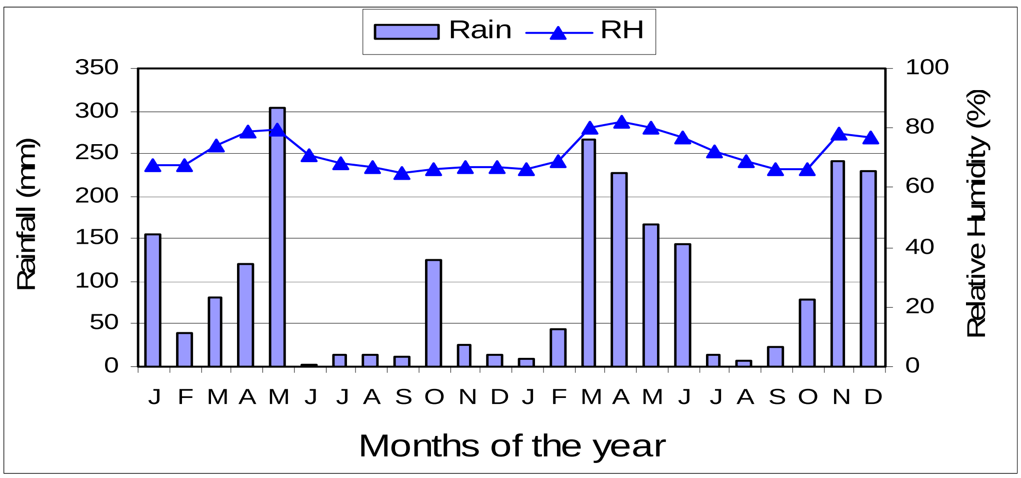


**Figure 1**. Relative humidity (RH, in %) and rainfall (mm) recorded for all days in 2005 and 2006 in Dar es Salaam.

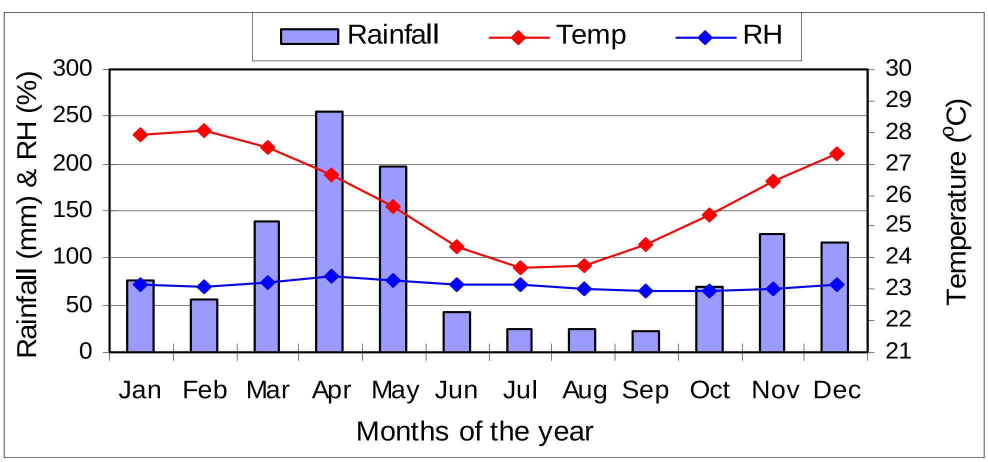


**Figure 2**. Monthly average of atmospheric temperature ($^{o}$C), relative humidity (RH, in %) and rainfall (mm) for the 33-year period 1971-2003 in Dar es Salaam.

In Dar es Salaam the 2005 dry season was cool and dry with a mean daily maximum temperature of 27 ºC and a total rainfall of 5 mm. The 2006 wet season the weather was hot and wet with a mean daily maximum temperature of 28 ºC and a total rainfall of 306 mm, as compared to the 2005 wet season (total rainfall of 102 mm) which was rather dry with a mean daily maximum temperature of 29 ºC. The ambient temperature during the three measurements was minimum in August 2005 (about 20 °C) and reached a maximum in May 2005 (about 33 °C). The average relative speed for the 2005 wet season, 2005 dry season and 2006 wet season measurement were 65, 60 and 70% respectively. The corresponding values for the average wind speed were 4.1, 5 and 3 m/s respectively. The ambient air quality in Dar es Salaam were therefore influenced by the meteorology; with higher pollution observed during the dry season than in the wet seasons (Fig. 5). In the wet season, there is substantial removal of aerosol particles and other pollutants by wet deposition, whereas in the dry season soil dust dispersal is enhanced (because of dry soils) and there is an increased possibility for photochemical formation of aerosol particles from their gaseous precursors.

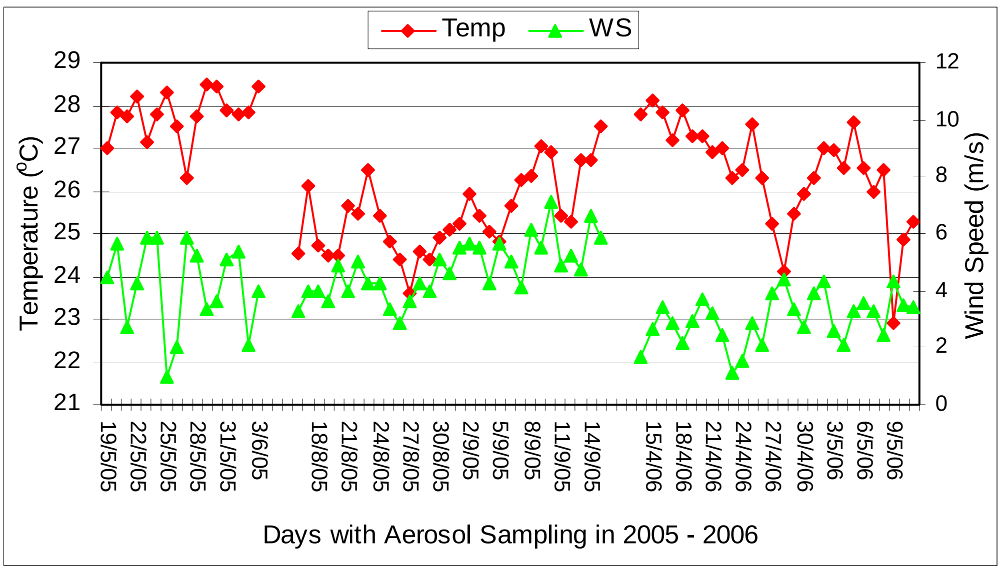


**Figure 3**. Daily average temperature (°C) and wind speed (m/s) recorded for the study period in Dar es Salaam.

## Air Mass Climatology

Long-range transport of air masses has an impact upon the air particles composition at a sampling site, as it brings in particles from distant source areas. Air mass backward trajectories are useful to determine possible sources of aerosol particles and have been extensively used in the literature (Brankov et al., 1998). In this study air mass back trajectory analyses were performed daily during the 2005 wet and dry season and 2006 wet season using the Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT version 4) (Draxler and Rolph, 2003) utilizing the Final Model Run (FNL) meteorological data set. Five-day isentropic backward trajectories were computed for arrival levels of 100, 500, and 1500 m above ground level (agl) at 00:00 and 12:00 UTC arrival times for night and daylight periods, respectively. The daily air mass back trajectories were categorized into four different sectors at the arrival levels of 100, 500, and 1500 m agl (Fig. 4). The allocated sectors were T1 (Oceanic); T2 (Oceanic, over Madagascar); T3 (Madagascar and/or oceanic over continental, mainly through Mozambique and Tanzania) and T4 (Continental, over Tanzania, Mozambique, South Africa). Allocation to a particular sector was made using criteria similar to those used by Traub et al. (2003). It was observed that there were seasonal airflow characteristics for Dar es Salaam, expressed as percentage (%) of daily air mass back trajectories arriving from each of the defined four sectors for each of the three arrival levels. T2 was the most frequent arrival sector in the 2005 measurements, followed by T3, whereas this order was reversed in the 2006 measurement. However, there was a fair similarity between the four defined sectors for each of the three arrival levels especially during the 2005 dry season and 2006 wet season measurements.

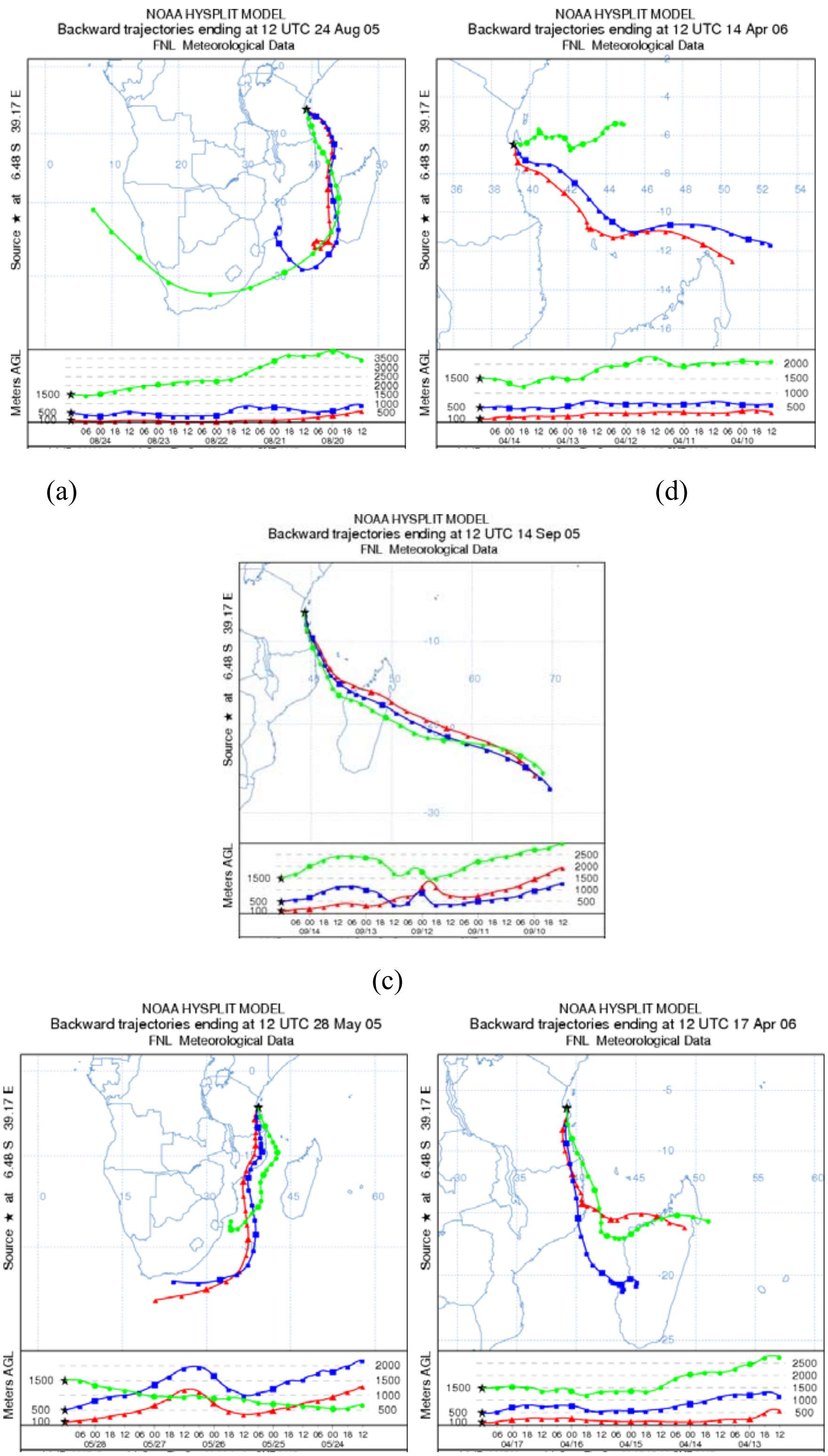


**Figure 4**. Typical examples of five-day back trajectories for air masses arriving at Dar es Salaam during 2005 and 2006 measurements. In (a) and (d) mainly oceanic origin-T1; (c) oceanic origin over Madagascar-T2; (b) and (e) oceanic or Madagascar origin over continental-T3.

**Impact of Meteorology on the PM mass**

The levels for the PM mass and other aerosol components in different size fractions and for different seasons in Dar es Salaam have been reported by Mkoma et al., (2009a,b; 2010). Higher concentrations of most of the PM mass, carbonaceous species, water-soluble inorganic ions and elements were observed during the 2005 dry season and the lowest median concentration during the 2006 wet season. Figure 5 shows the median concentrations and concentration ranges for the PM10 mass in Dar es Salaam during different seasons (Mkoma et al., 2009a,b; 2010). The highest median and maximum concentrations for the PM10 mass were obtained during the 2005 dry season and the lowest median and minimum during the 2006 wet season. In Dar es Salaam, both clean marine air masses and precipitation scavenging effects due to rain caused the low concentrations of various aerosol components during the 2006 wet season campaign. In the 2005 dry season campaign, the air masses originated mainly from the southern African subcontinent (see trajectories Figs. 4a,b) and this, combined with the dry and cold weather, biomass burning and soil dust dispersal (with little vegetation) gave rise to high aerosol concentrations in Dar es Salaam. Therefore, variations in ambient PM10 levels observed during the sampling seasons resulted from variations in sources strengths and in meteorological conditions, such as mixing height and precipitation. However, the main sources of the PM10 mass at this site are expected to be primary sources, i.e., traffic, biomass burning and soil dust dispersal, but gas-to-particle conversion processes may also contribute.

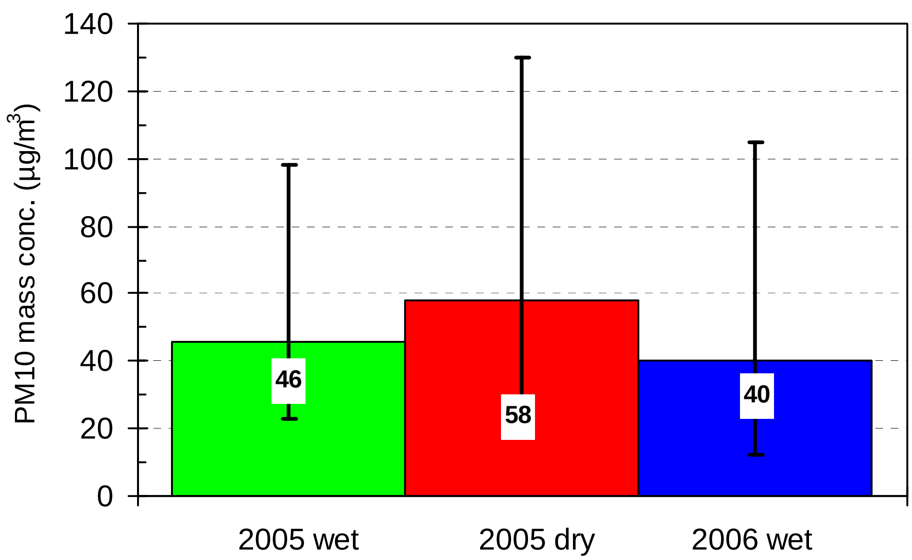


**Figure 5**. Median concentrations and concentration ranges (µg/m$^3$) for the PM10 Mass in Dar es Salaam during three seasons (Mkoma et al., 2010).

## CONCLUSION

The influence of the meteorological parameters on the air quality of Dar es Salaam was investigated during the dry and wet seasons of 2005 and 2006. The high levels of atmospheric particles were obtained during the dry season and the lowest during the wet season. Differences on the atmospheric particles levels between the dry and the wet seasons can be attributed to the differences in meteorological conditions. In order to obtain a better picture, other studies along the same lines in several other parts of the country are needed.

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