MINERALOGICAL CHARACTERISTICS OF HARMATTAN DUST IN ILORIN, SUB-SAHARA AFRICA

Falaiye, O. A.[1], **Yakubu, A. T.**[1], **Aweda, F. O.**[1], **and Abimbola, O. J.**[2]
[1] *Department of Physics, University of Ilorin, Ilorin, Nigeria,.*
[2] *Physics Department, College of Education, Azare, Nigeria.*
Corresponding Author: sesantayo2001@yahoo.com or falaiye.oa@unilorin.edu.ng
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ABSTRACT

Mineralogical study was carried out on harmattan dust samples collected over Ilorin (8° 32' N, 4° 34' E) sub-Sahara region of West Africa. Minerals such as quartz [SiO_2] (76.5%), gibbsite [$Al(OH)_3$] (7.1%), rutile [TiO_2] (5.8%), goethite [$Fe_2O_3.H_2O$] (4.6%), halloysite [$Al_4Si_4O_{10}(OH)_8 \cdot 8H_2O$] (3.9%) and kaolinite [$Al_4Si_4O_{10}(OH)_8$] (2.1%) were detected. Quartz, halloysite, microcline and mica were similarly identified in harmattan dust sampled at Ile-Ife. However, gibbsite, rutile, goethite which were identified at Ilorin were not detected at Ile-Ife, while microcline and mica detected in Ile-Ife were not observed at Ilorin. The mineralogical composition of the harmattan dust at a locality is most probably determined by the source and the distance from the source of the harmattan dust.

Keywords: Bodele Depression, Harmattan Dust, Mineralogy, Ilorin.

INTRODUCTION

During the period of this study (November to March), the West African region experiences the prevailing north-easterly wind regime known as Harmattan (Falaiye *et al.*, 2003). This dry wind transports and deposits the Saharan dust over the entire region and extends as far as to the Gulf of Guinea. The dust plumes predominantly originate from the Bodele Depression in the Chad Basin (Bertrand *et al.,* 1979) and accounts for the dust particles deposited over the region. According to Balogun (1974), two sources of dust plumes were identified and these include the dust originating from the region around Mauritania, Algeria and Morocco which accounts for most dust observed over the Atlantic extending as far west as the Barbados Island and dust originating from the Chad Basin which accounts for the dust observed over countries around the Gulf of Guinea and as far as South America (Glaccum and Prospero, 1980; Shutz *et al.*, 1981; Prospero *et al.,* 1981; Muhs *et al.,* 1990; Ott *et al.,* 1991; Rognon and Coude´-Gaussen, 1996.

Since the last few decades, the enormous spread of Saharan dust outbreaks can be witnessed using satellite imagery; hence the identification of the Faya Largeau, Chad, as the key source area of north-west African eolian dust (McTainsh and Walker, 1982). This was confirmed using satellite images (Prospero *et al.,* 2002, Stuut *et al,* 2005). Several selective transport mechanisms were recognized along the pathways of dust: downwind decrease in grain size of the wind-blown material from ~90 mm on the Cape Verde Islands (Glaccum and Prospero, 1980) to ~5 mm in the Caribbean (Talbot *et al.,* 1986) and downwind depletion of quartz grains and enrichment of clay minerals, related to the relatively larger mass median diameter of quartz, and, consequently, its greater settling velocity in the atmosphere (Glaccum and Prospero, 1980). Since the majority of land-derived sediments in this part of the Atlantic Ocean are of eolian origin, often the terrigenous sediment fraction was taken to be windblown (deMenocal *et al.,* 2000; Moreno *et al.,* 2001; Sarnthein *et al.,* 1982), although admixture of fluvial-transported or laterally adverted sediments were found to play a role as well (Holz *et al.,* 2004; Koopmann, 1981; Ratmeyer *et al.,* 1999; Zabel *et al.,* 1999). Hence the collection of dust sample at a site can also be used to do a reconstruct of the Aeolian origin of the dust and associated environmental changes.

Harmattan dust production in the Chad Basin was estimated to be up to $6.3X10^8$ and $7.1 X 10^8$ t/yr in 1981 and 1982 respectively (McTanish and Walker, 1982). In Sahelian and Saharan Africa, harmattan dust transport is accomplished by the north-easterly trade winds (Schwarghart, 2007). The effect of this dust is seriously felt on the environment (Falaiye, 2008; Adefolalu, 1984; Adedokun *et al.,* 1989). Health cases such as, cough, catarrh and respiratory related diseases, are mostly reported in the hospitals during the harmattan period (Carlson and Prospero, 1972; Shutz, 1980).

The great sensitivity of dust emissions to climate has been recognized, not only for the potential feedback mechanism of dust production and desertification (Prospero and Lamb, 2003) but also for the various roles eolian material deposited to the ocean surface may potentially have (Stuut *et al,* 2005). In some cases it may be responsible for new production in areas where the iron-rich dust acts as a fertilizer (Martin and Fitzwater, 1988), whereas in other regions it may cause starvation of marine organisms, e.g., because of the fungi carried along with the dust (Shinn *et al.,* 2000).
The Harmattan is influenced largely by the variability in the incursion of air pressure into the Saharan region. This fact has been pointed out by various meteorological observers (Samway, 1975; Adedokun *et al,* 1989). High pressure to the north of Bodele Depressions intensifies the north-easterly trade winds leading to an increase entrainment of dust in the Bodele Depression (Adedokun *et al.,* 1988; Schwanghart and Schutt, 2007).

Falaiye (2008) reported that the aerosol optical thickness (AOT) during the Harmattan months can be extremely high and ranges from 1.0 to 4.0. This contributes significantly to the attenuation of incoming solar radiation, thereby leading to reduced visibility (Pinker *et al.,* 1994). The harmattan spells are often accompanied by droplets in the evening and early morning temperatures associated with an oscillation of the axis of the subtropical high (Adedokun, 1978; Adedayo, 1980; Adedokun *et al.,* 1989). The dust spell may last up to three to five days, but on occasions of advection of dust from a line rather than a point source, the persistence may be longer than ten days (Adedayo, 1980; Adedokun *et al,* 1989).

This paper intends to give a report on the preliminary mineralogical investigation conducted on harmattan dust deposited over Ilorin (8°32' *N*, 4°34' *E*). This study is a follow up to the effort of Adedokun *et al.* (1989) who conducted a similar study in Ile-Ife (7.29°*N*, 4.34°*E*). Earlier studies on atmospheric aerosol optical depth over Ilorin have not included the mineralogical analysis of the harmattan dust. Stuut *et al.* (2005) conducted a similar study along a transect up the west African coast, between Latitudes 40°*N* and 20°*S* and Longitudes 20°*E* and 20°*W*. These region falls within the source point of the dust, i.e., Bodele's Depression and Faya Largeau and the trajectories of its motion. Hence, a study of this type at Ilorin (8°32' *N*, 4°34' *E)* will enhance and add to the understanding of the effect of the harmattan dust on the climatology of the region.

SITE DESCRIPTION

Ilorin (8°32' *N*, 4°34' *E*), a city in the sub-Sahel region of the central state of Nigeria in West Africa, is in the transition zone between the deciduous forest of the south and the savanna of the north. Precisely, Ilorin is located at the upper tip of the guinea-savanna zone with a mean monthly average temperature of about 30.2°*C* and average annual rainfall of about 873 *mm* (Olaniran, 1991a&b).

Figure 1: Experimental Location (Indicated by the Red Arrow) and the Possible Source of the Harmattan Dust (Indicated by the Red Rectangle)

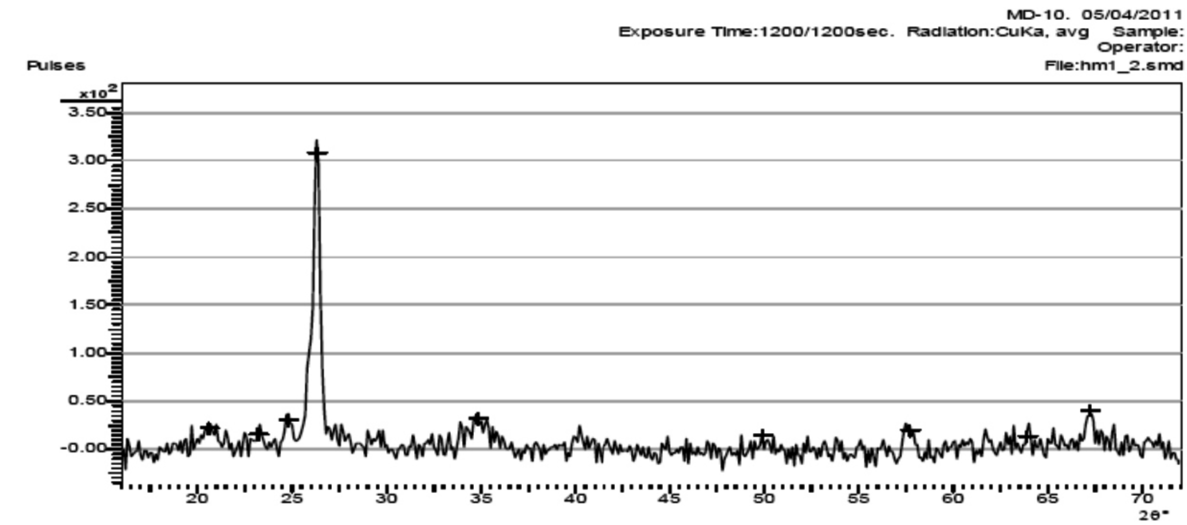
MATERIALS AND METHODS

Clean Petri-dishes were exposed on an elevated platform in twelve different locations around Ilorin metropolis including the University of Ilorin. Some of the dishes were exposed to collect dust particles for a period of 24 hours, others for a week and some over a period of three months (January-March). A total of 36 samples were collected and stored in desiccators prior to analysis in order to avoid contamination which could influence the results. During the collection process, measures such as keeping the sample containers away from public roads and high ways were taken in order to minimize the input of local dust.

Mineralogical analysis was carried out on the harmattan dust samples collected from each location. Sample from each location stored in a sample bottle was pressed on a sample holder and mounted in the XRD (X-ray diffraction) machine and analysis was conducted on the samples. The XRD machine, model MD-10, installed with an X-ray tube radiating C_uK_a within a wide range of angles and operating at 25 kV, 0.4 mA. The diffractogram of the samples was interpreted by matching the peaks obtained to those of standard minerals established by Brown (1951), Carrol (1970) and JCPDS (Joint Committee on Powder Diffraction Standard) (1980) mineral powder diffraction file.

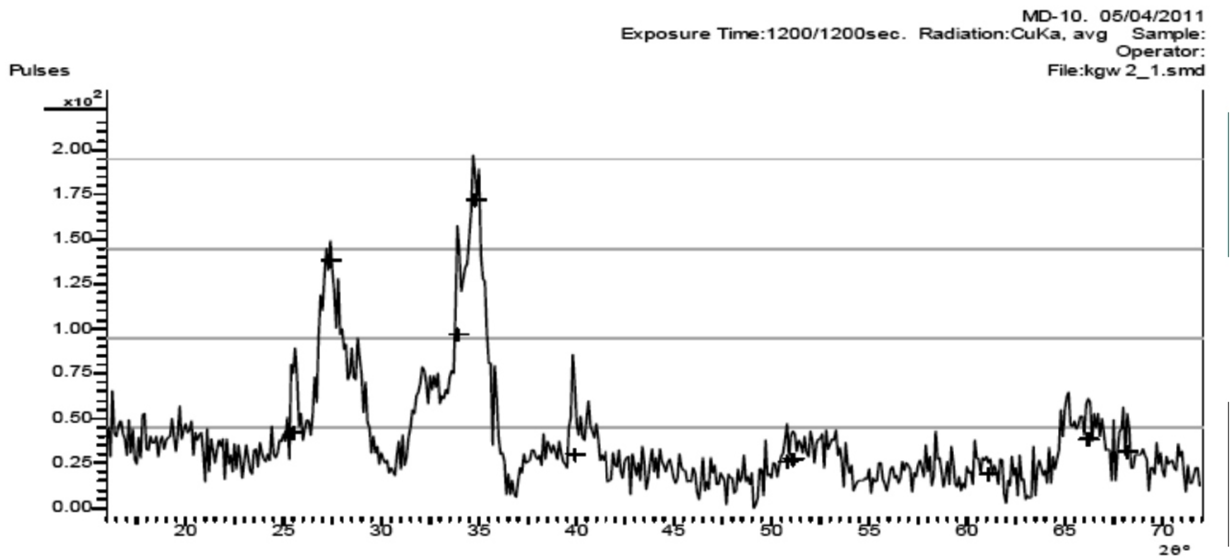
RESULTS AND DISCUSSION

Typical diffractograms of the mineralogical analysis of the aerosol samples are presented in Figures 2 and 3. The figures show that quartz, gibbsite, rutile, goethite, halloysite and kaolinite are the major constituent



2θ°	d	I int	I max	I rel	I corr	FWHM
20.53	4.32605	940	18.1	11.9	13.5	0.69583
23.15	3.84115	280	14.8	3.5	3.8	0.2538
24.74	3.59845	518	24.0	6.6	6.7	0.2897
26.22	3.39903	7907	279.0	100.0	100.0	0.39195
34.76	2.58060	614	16.0	7.8	7.0	0.52942
49.89	1.82793	729	18.6	9.2	7.7	0.51523
57.61	1.59986	1202	25.6	15.2	12.4	0.61813
63.89	1.45689	316	13.4	4.0	3.2	0.31479
67.14	1.39412	769	30.9	9.7	7.8	0.33635

Figure 2: Typical X-ray Diffraction Result of the Harmattan Dust Sample Collected Showing a Single Peak.



2θ°	d	I int	I max	I rel	I corr	FWHM
25.48	3.49505	749	35.9	21.6	24.1	0.28089
27.36	3.25964	2768	132.5	79.7	86.4	0.28901
33.85	2.64783	1894	90.7	54.5	54.9	0.28826
34.76	2.58078	3475	166.4	100.0	100.0	0.28795
39.90	2.25929	499	23.9	14.4	13.9	0.28497
50.71	1.80017	417	20.0	12.0	11.0	0.27343
51.04	1.78937	449	21.5	12.9	11.9	0.27324
61.05	1.51778	262	12.5	7.5	6.7	0.28253
66.10	1.41347	683	32.7	19.7	17.5	0.28034
68.11	1.37658	535	25.6	15.4	13.7	0.28334

Figure 3: Typical X-ray Diffraction Result of the Harmattan Dust Sample Collected Showing Multiple Peaks.

minerals present in the harmattan dust that is collected over Ilorin. The results show that quartz is dominant as it constitutes an average of 76.47% of the dust sample while other minerals are present either in small quantities or traces as shown in Table 1. These results are in line with that of Adedokun *et al.* (1989) except that microcline and mica which were detected at Ile-Ife (Adedokun et al., 1989) were not observed in Ilorin.. Results obtained from Ilorin and Ile-Ife are compared in Table 1. Minerals such as gibbsite, rutile and goethite are found at Ilorin but are not present at Ile-Ife. Ile-Ife is situated some 125 km south of Ilorin. Rutile and goethite being relatively heavier minerals (see Table 1) may have been fully deposited before the harmattan dust reaches Ile-Ife. This could account for the non-detection of both minerals at Ile-Ife.

Table 1: Percentage Proportion of Minerals Present in Harmattan Dust at Ilorin Compared To that of Ile-Ife (Adedokun et al., 1989).

Mineral	Specific Gravity	Ilorin (%)	Ile-Ife (%)
Quartz [SiO_2]	2.65	76.47	74.78
Gibbsite [$Al(OH)_3$]	2.35	7.09	-
Rutile [TiO_2]	4.2	5.78	-
Goethite [$Fe_2O_3.H_2O$]	4-4.2	4.59	-
Halloysite [$Al_4Si_4O_{10}(OH)_8 \cdot 8H_2O$]	2.6	3.93	1.45
Kaolinite [$Al_4Si_4O_{10}(OH)_8$]	2.6	2.09	10.29
Microcline [$KAlSi_3O_8$]	2.56	-	17.63
Mica [Si_4O_{10} Sheet Structure]	2.7-3.1	-	2.54

(Source of Specific Gravity: Read, 1973)

However, microcline and mica have specific gravity values that are in the range of that of quartz, halloysite and kaolinite. The non detection of microcline and mica at Ilorin could not be explained on the basis of specific gravity. Perhaps the microcline and mica may have been lifted and transported higher above the Ilorin location but deposited at Ile-Ife. Perhaps, the composition of the Ilorin and Ile-Ife harmattan dust could have been different due to different sources.

Both results however indicate that the harmattan dust is quartz abundant. Quartz abundance can be associated with loose sandy sedimentary rock whose topsoil is subjected to continuous wind action and consequent erosion.

CONCLUSION

Harmattan dust lifting, transportation and deposition, occur naturally. Studies have identified two key sources, the region around the Mauritania, Algeria and Morocco and the Bodele Depressions in the Chad Basin, which is mainly responsible for the harmattan-dust deposited across Nigeria (Balogun, 1974).

In this study, mineralogical constituent of harmattan-dust deposited in Ilorin is investigated, and minerals such as quartz, gibbsite, rutile, goethite, halloysite and kaolinite were found to be present in various quantities with quartz the most abundant. The constituents compared with the result of a similar study carried out by Adedokun *et al* (1989), at Il-Ife, Nigeria, which also showed that quartz is the most abundant constituent. Some minerals such as gibbsite, rutile and geothite found to exist in the harmattan dust deposited at Ilorin are not present in the dust deposited at Ile-Ife, while microcline and mica found at Ile-Ife are not present in the dust deposited at Ilorin. The mineralogical composition of the harmattan dust at a locality is most probably determined by the source and distance from the source of the harmattan dust.

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