PHYSICAL CHARACTERIZATION OF SETTLED INDOOR/OUTDOOR DUST PARTICLES USING SCANNING ELECTRON MICROSCOPE (SEM)

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Abstracts - In recent years, Harmattan, a dusty weather condition characterized by thick smog-like suspended particles and dust storm are the peculiar events that happen during ¾ of the year in the Sahelian regions including Damaturu Town, Nigeria, resulting into heavy dust deposits especially indoors. These weather events with the increased in temperatures are considered to be the result of climate change. The inhabitants of the Damaturu community are always inflicted with different ailments; respiratory tract infections, asthma, gastrointestinal infections and different ailments associated with the dusty nature of the immediate environment. This brought the need to investigate the nature of the settled indoor as well as outdoor dusts. Vacuum cleaner bag dusts were collected from indoor of some Nigerian and UK homes, and outdoors during the seasonal dusty weather events (Harmattan and Storm), and also when there was no weather event. The dusts were sieved and the (150 µm size) particles were examined using scanning electron microscope (SEM).
The physical characterization of the settled dust samples has revealed the various shapes and sizes, and elemental composition of the dust samples indicating that some of the dust fractions were the respirable fractions and also the dust contained PM_{10} to $PM_{2.5}$ fractions with possible health effects. The elemental compositions were indicative of the diverse nature of the dust particle sources, which showed dust as a complex matrix.

Keywords - Harmattan dust, SEM, Storm dust, Indoor/Outdoor

I. INTRODUCTION

Climate change has resulted to different weather and climate patterns. In many dryland areas such as the sub sahelian regions the climate has become even more arid and rivers, lakes and underground water sources are drying up resulting into increased dryness of the atmosphere and increased desertification.
In recent years, the onset of rainy season (June to October) in most parts of the north-eastern semi-arid region of Nigeria is characterized by heavy dust storms (smog-like), accompanied by reduced visibility for 3 – 5 minutes. The storms last between 3 to 15 minutes and are mostly followed by torrential rains with thunderstorms, leaving behind heavy dust deposits, which settle down on every availablesurface. They occur most often in areas with less vegetation cover and relatively dry zones, and high temperatures within the sub-Saharan region. During winter (November to March), Harmattan (characteristic northeast wind, which blows southwards) with thick haze containing heavy particulate materials may persist in the atmosphere continuously for days to weeks. These events are thought to bring about high exposure of people to dust particles (as well as gases and vapours) in the local communities.

1.1 Dust: Dust is generally considered to be particulate matter that is found either suspended in the air or settled onto a surface, and originates from a number of sources including soil, abrasion of materials, pesticides, asbestos, pollen, bacteria, shed skin, cigarette smoke and dust mites [1], [2].(Morawska and Salthammer, 2006a; Leese et al., 1997).
Settled dust has been found to be a good surrogate for indoor air pollution[3].(Mitchell et al., 2007) and is collected for health monitoring purposes. Air pollution was first noticed as a problem of city dwellers, but now, it is acknowledged as a problem of global significance[4].(Zhang and Smith, 2003). Air pollutants both indoors and outdoors, are regarded as significant cause of health problems worldwide in both urban and rural environments[5].(World Health Organization, 2005). The increased exposure to indoor pollutants in dust may result in health effects especially in children; these include retarded growth, learning disabilities, allergies, cancer, nervous system damage, and other illnesses[6],[7].(Roberts and Dickey, 1995; Roberts et al., 2009).

1.2 Dust storm: is often used in the context of desert sandstorms, especially in the Sahara, when, in addition to fine particles obscuring visibility, a considerable amount of larger sand particles are blown closer to the surface [8].(Griffin et al., 2002). Dust Storm is a meteorological phenomenon common in arid and semi-arid regions, which is characterized by a strong, turbulent wind carrying large clouds of dust. In a large storm, clouds of fine dust may be raised to heights well over 10,000 feet (3 km) and carried for hundreds or thousands of miles[9],[10]. .(Goudie and Middleton, 2001).
The Sahara Desert is a key source of dust storms, particularly the Bode'le Depression, and an area covering the confluence of Mauritania, Mali, and Algeria[10]..

1.3 Harmattan Dust: Harmattan dust (fine particle dust, typically 0.5 µm–10 µm) is known to rise in the Sahara desert and is carried south by winds from that area. The Harmattan is a dry and dusty wind resulting from storm activities in the Bilma and FayaLargeru area in the Chad Basin. This raises large amounts of dust into the atmosphere, which is then carried southwest by the predominant north-east trade winds, from the Sahara into the Gulf of Guinea, including Nigeria and other west African countries, between November and March (winter) every year[11].(Achudume and Oladipo, 2009).

1.4 Background of study: People in the Damaturu community of northeastern Nigeria spend most of their time indoors because of the harsh weather conditions: cold, dry, strong, and dusty wind during Harmattan, thick dust during storm, and heavy downpours during the rainy season. The habit of using fire wood and kerosene in cooking, and diesel/petrol powered generators for electricity are potential factors of increased indoor pollution including dust particulate deposition. Other activities like the burning of local and assorted incense, burning of mosquito coils and application of aerosols as insect repellents indoors and outdoors could also generate particulate, organic, and elemental pollutants, which may linger in the air or cling to dust particles and settle on raised surfaces and floors[12].(Mohammed and Crump, 2013). The pollutants present in air and dust may potentially cause exposure via inhalation and ingestion of house dust particles adhering to food and objects, or via direct absorption through the skin[13].(Lewis et al., 1995). These natural and anthropogenic sources of airborne and deposited dust are a risk to the health of the local population amongst which there is a general acceptance of the adverse outcomes as these are considered as arising from natural phenomena and thus a situation that cannot be changed.

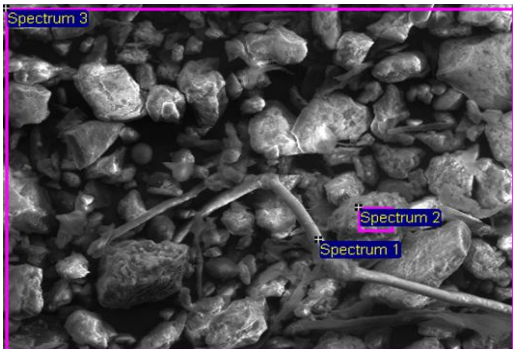
II. METHODOLOGY

We carried out the scanning electron microscopy in the school ofapplied sciences laboratory (building 39), Cranfield University with an environmental scanning electron microscope Philips -XL30 ESEM by modifying the method[14].
We collected Vacuum cleaner bag dusts from 10 households in Nigeria and UK homes.We analyzed a standard reference material for organic chemicals (SRM 2585) dust alongside the sampled household dusts. The dusts were sieved and the (150 µm size) particles were examined.

2.1 Scanning Electron Microscopic Procedure:
We made use of adhesive carbon tape fixed on pin stubs, usually used for mounting samples to prepare the sample for analysis. The adhesive surface of a separate pin stub was gently pushed into each of the bulk dust samples and then the stub with adhered dust particles was positionedinto the carousel in the sample chamber of the SEM. The samples were placed at labelled coordinates for ease of identification of sample images and spectra. The microscope chamber door was screwed tightly to enable a vacuum (without a sufficient vacuum, the electron beam generated by the electron gun ould encounter constant interference from air particles in the atmosphere, blocking the path of the electron beam).
The microscope was turned on from the attached computer and the vacuum pressure was checked. Electrons were then accelerated onto the samples from the in-built electron gun resulting in interactions with the atoms of the target samples. The characteristic x-rays of different elements in the samples were detected and separated as energy spectra by energy-dispersion. The images of samples generated from detection of the scattered electrons were viewed and adjusted to the required magnifications. In some instances, points of interest on a particular particle was magnified and saved. The element spectra of individually chosen particles were examined, and in some instanceswe recorded the general spectrum of the complete visible sample surface micrograph.

III. RESULTS AND DISCUSSIONS

T The sizes of the particles observed from the Nigerian settled dustranged between100µm and 2µm. Representative micrographs (100µm) are shown in Plates 1 and 2. The spectra captured by the SEM showed predominantly peaks of silica (Si) and iron (Fe) followed by other elements -; calcium (Ca), magnesium (Mg), sodium (Na), titanium (Ti), potassium (K), sulphur (S), and aluminium (Al). An example of the elemental composition is shown in Table 1. Filamentous particles were seen in the Nigerian samples AH, FHO and YH with those in MH dust shown to be segmented which might have originated from hair strands, dead plants, or clothes. LH dust contained a spongy (mass) shape that resembles soot or other organic cells skin flake (Plate 2).



100 µ m

Plate 1. SEM image of MH (Nigerian) Dust

Spec	Amount of elements in weight%											
	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe
1	76.2		0.8	3.4	12.7		0.3	0.7	1.4	2.4	0.7	1.6
2	60.2	0.7	1.4	8.4	18.1	0.4	0.2	0.3	1.2	4.3	0.4	4.5
3	59.7	0.7	0.8	4.8	24.1	0.3	0.4	1.0	2.2	3.4	0.1	2.5

Table 1. Element composition of particle spectra in MH dust

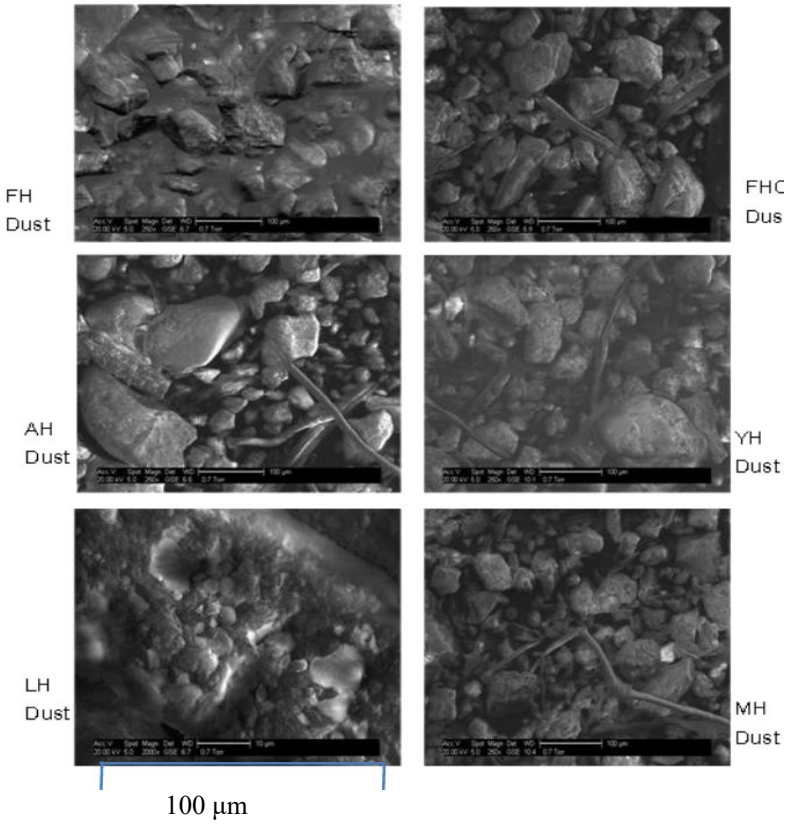


Plate 2. SEM images of Settled Dust Samples from Nigerian homes

The images of UK samples were mostly amorphous, puffy sheet-like and clustered, and spongy mass with irregular shapes. The particles from different dusts have different elements compositions, indicating the difference in nature and sources of the particles. The presence in UK dusts of particles dominated by carbon (C), phosphorus (P), potassium (K), and copper (Cu) that were not observed in the Nigerian dusts indicates a variation in the elemental composition of the dusts from the different geographical locations (Plate 3 and Table 2).

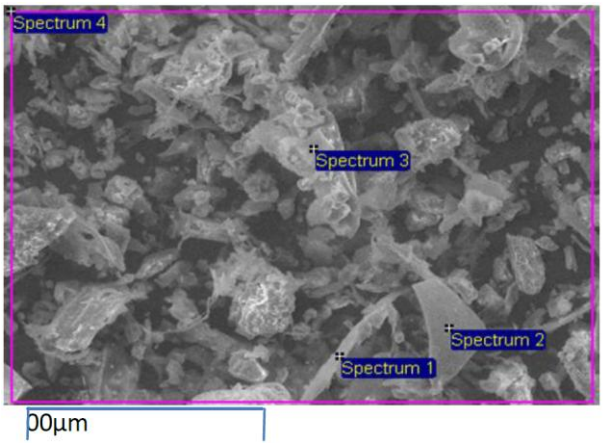


Plate 3. SEM picture of particles in DH (UK) dust

Spectr	Amount of elements in weights%													
	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Cu	Total
1	51.2	38.3	0.4		2.0	4.4	-	1.2	0.5	0.3	1.3	0.4		100
2	26.2	53.3	-	0.1	1.3	17.3	-	0.1	0.1	0.1	1.0	0.2	0.2	100
3	58.1	32.2	0.9	0.4	1.9	2.3	0.1	0.8	0.8	0.4	1.4	0.7	-	100
4	48.9	36.2	0.4	0.2	3.2	6.1	-	0.7	0.4	0.7	1.9	1.3	-	100

Table 2. Elemental composition of DH dust particles

For comparison of the SEM images of the dust particles, images of known samples (hair strand and skin flakes) were also taken. The images of LH dust showed some resemblance with that of the skin flake, while almost all the images showed the presence of particle images which resemble that of hair strand. The SEM images of skin flake and hair strand are shown in Plates 4a and 4b. The elemental compositions of the two known samples (hair strand and skin flake) were also found to be similar to the particles in spectrum 1 in DH dust and spectrum 1 in MH dusts.

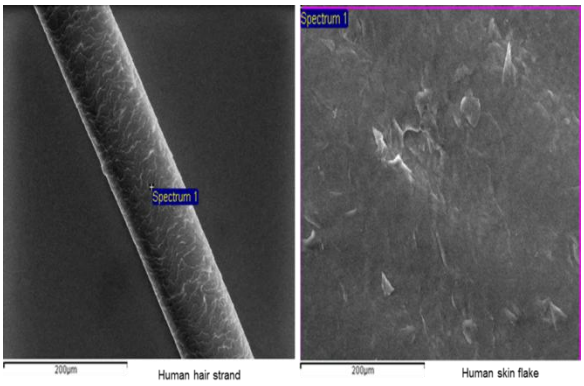


Plate 4a. SEM images of hair strand Plate 4b. skin flake

	Amount of elements in weights%										
	C	N	O	Al	Na	Si	S	Cl	K	Ca	Total
Skin flake	58.8	9.7	29.2	-	0.3	0.1	0.9	0.5	0.5	-	100
Hair strand	67.6	5.7	20.8	0.2	-	-	5.2	-	-	0.5	100

Table 3. Elemental composition of hair and skin

3.1 SEM analysis of Harmattan Dust and Storm Dusts:

The SEM images of Harmattan dust particles were shown to be dominated by perforated cylindrical-shaped particles of 2 to 50µm in size (Plate 5). The elemental spectra of the visible Harmattan particles were shown to contain the elements carbon (C) and oxygen (O), potassium (K), calcium (Ca), sulphur (S), iron (Fe), titanium (Ti), silica (Si) and sodium (Na) (Table 3). The distribution of the elements signifies that the particles were from organic sources. The arrays of images shown in Harmattan sample were similar to those reported by Eckardt et al., (2005), and were suspected to be possibly of the crushed diatoms from dried lakes[15]. (Todd et al., 2005). The Harmattan particles sources are believed in the Bodele depression around the dried Lake Chad. The SEM picture (Plate 5) was found to be similar with that of the sample collected from the Bodeledepression[15] (Plate 6) as reported by Todd et al., 2005.

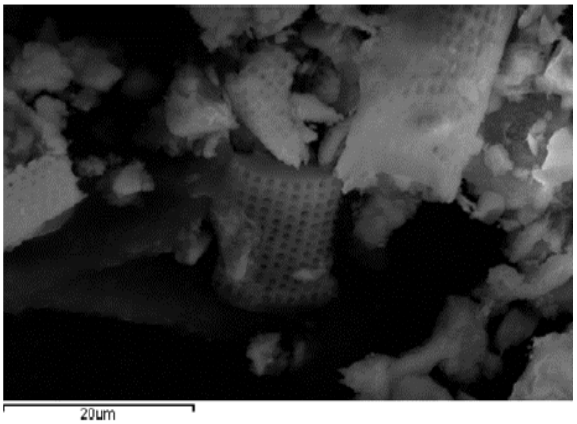


Plate 5. SEM Image of Harmattan Dust

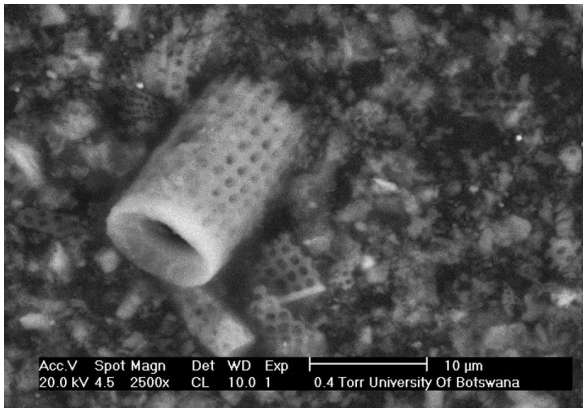


Plate 6. Crushed diatom fragments[14]

Amount of elements in weights%									
C	O	Na	Si	S	K	Ca	Ti	Fe	Total
39.9	34.1	0.7	0.2	2.4	5.1	3.3	1.2	2.4	100

Table 4. Elemental composition of Harmattan dust particles

The images of the storm particles were found as mostly unclustered, rectangular sharp-shapes of quartz (sand) particles (Plate7). The element content of storm dusts particles showed the elements O, dominating followed by C, Si, and Fe peaks Ca, S, K, Al, and Ti (Table 4). The Spectrum 1 in Plate 7 might be from an organic source, whilst spectrum 2 looked like a sand particle because of the dominant O and Si content.

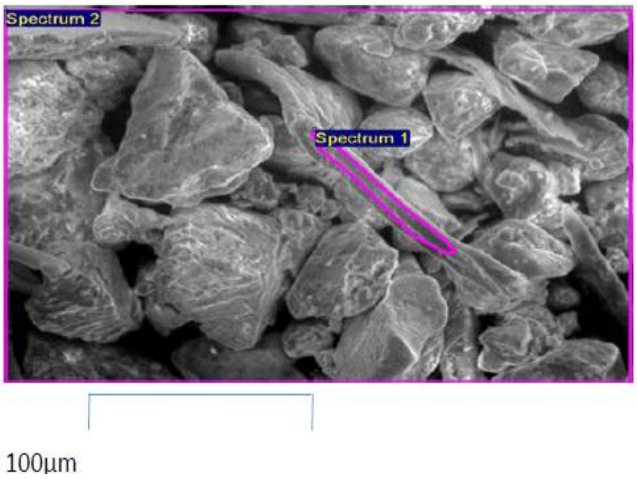


Plate 7. SEM image of Storm Dust

	Amount of elements in weights%											
Spectrum	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	Fe
1	31.7	46.5	0.7	4.2	11.8	0.4	1.1	1.1	1.2	0.2	1.1	
2		54.7	0.9	0.2	6.8	27.9		1.1	1.8	3.7	0.6	2.3

Table 5. Elemental composition of Storm Dust particles

The dust particles were found to contain mixtures of particle of different shapes and sizes which might have originated from different indoor and outdoor sources. The characteristic strong winds that blow from outside the buildings during the dusty events might be the cause of high presence of sand fractions in the Nigerian dusts. The presence of soot on the other hand may be from the fossil fuels combustion and wood burnt during cooking and various activities. The Harmattan particles were found to contain the crushed diatoms believed to be transported over hundreds of kilometres from Bodele depression by the seasonal north-eastern trade wind that blows during Harmattan season as reported [15]

IV. CONCLUSIONS

The physical characterization of the settled indoor dust samples using the Scanning Electron microscope (SEM) has revealed the various shapes and sizes, as well as the elemental composition of indoor dust and outdoor dust. House hold dust which is often generated from various sources. Vacuum cleaner bag dusts collected from households and from outdoors of the homes were used for the SEM analysis and the results obtained made it the best choice of sampling method[14].The preliminary results obtained gave a profile of what is contained in the dust which gave information on the exposure risks to household dust in the indoor environment and the possible human health effects.

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