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Measurement and Analysis of Electric Field in Zaria

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Abstract: This paper presents the analysis of the static electric fields in Zaria, Nigeria based on measurements carried out using a data acquisition system interfaced with a digital electrostatic field strength meter (Model 257D). The acquired electric field data are captured by a computer using the Microsoft Office Excel Program. The focus of the analysis is determining the effect of environmental factors as temperature, pressure and relative humidity on the static electric field during the Harmattan (March) and non-harmattan period (April – March). The plots of average electric field against the variation of the environmental factors were used as the qualitative analytical tools, and conclusion was drawn to the fact that the measurement of static electric field in Zaria is influenced by the co-related environmental factors to harmattan intensities.

Keywords: Measurement,-Electric-Field,-Harmattan

INTRODUCTION

Zaria is located within the co-ordinate position of latitude 11^0N and Longitude 8^0E above sea level. This falls within the Sahara zone, where harmattan activities exist due to the operation of the North-East trade wind. Harmattan is a natural phenomenon which describe the very dry dust – ladan atmosphere, which rises in the Sahara desert and is carried south by winds from that area within the West-Africa region periodically from October – March of every year. This is common to the dry season of the Savannah region.

Measurement of a given quantity is the result of comparison between the quantity (whose magnitude is known and a defined standard). In order for the results of measurement be meaningful, the standard used for the comparison purpose must be accurately defined and should be well acceptable. The apparatus used and the method adopted must be well defined. The measurement of the electric field in the atmosphere during dust storm in the Sahara region has been established in 2000[1]. The measurement of electric field in Zaria is achieved using a digital field strength meter, model 257D. This is a high quality, portable non-contacting static meter which produces consistent readings, with ease and offers years of trouble-free operations. It indicates surface voltage and polarity on objects up to plus or minus 20kV at a spacing of one inch with an accuracy of 10% of full scale[2,4,5]. This model was chosen because of the peripheral facilities it has for interfacing with other devices that may be required for measurement purposes.

The meter measures electric field strength in kilo Volts per centimeter. The system provides an output signal proportional to the surface charge accumulation, while making no physical contact to the material being monitored.

The measurement was done during harmattan months (March, 2007) and outside harmattan months (April – May, 2007) in an enclosed place. The chosen enclosed place was the Thermodynamic laboratory of the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, because of the available facilities for measuring the environmental factors, such as temperature, Humidity, pressure which are known to be co-related to harmattan intensity[2].

MATERIALS AND METHODS

Electric Field: It is customary and useful to introduce the concept of the electric field at this point. Electric field is a vector field. Given, a vector function of x. It is written as E(x) and is defined as the force that would be experienced by a charge *q* at x, divided by q^3. Thus, for a distribution of charges q_i at x_i, i = l,2,...,n,

$$E(X)=\sum_{i=1}^{n}\frac{q_1(x-x_i)}{|x-x_i|^3}\dots\dots\dots(1)$$

The electric field has the property of being independent of the 'test'

Charge *q*; it is a function of the charge distribution which gives rise to the force on the test charge, and, of course, of the test charge's position.

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At this point, let us introduce the charge density r*(x.)*, which is the charge per unit volume at, or very close to, x. This object is needed to integrate over a source distribution instead of summing over its constituent charges. Thus a sum is replaced by an equivalent integral,

$$\sum_{i=1}^{N} q_i \to \int d^3x \rho(x) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The charge density has dimension Q/L^3. In terms of ρ, the expression for the electric field can be written as

$$E(X) = \int d^3x' \rho(x') \frac{x - x'}{|x - x'|^3} \ldots\ldots\ldots\ldots(3)$$

In the particular case of a distribution of discrete point charges, it is possible to recover the sum in Eq. (1) by writing the charge density in an appropriate way. To do so, we introduce the Dirac delta function δ*(x*- a). It is defined by the integral

$$f(a) = \int dx f(x) \delta(x - a) \ldots\ldots\ldots\ldots(4)$$

Where *f(x)* is an arbitrary continuous function of x, and the range of integration includes the point x = a. A special case is *f*(x) =1 which leads to

$$\int dx \delta(x = a) = 1 \ldots\ldots\ldots\ldots\ldots(5)$$

Demonstrating, the normalization of the delta functions. From the arbitrariness of *f(x),* it can be concluded that δ*(x* — a) is zero, when *x* is not equal to a and sufficiently singular at x = a, to give the normalization property[3].

In other words, it is in essence, the charge density of a point charge (in one dimension) located at *x* = a. Some important relations involving delta functions are as follows:

$$\int_{a_1}^{a_2} f(x) \frac{d\delta(x - a)}{dx} dx = -\left.\frac{df(x)}{dx}\right|_{x=a} \ldots\ldots\ldots\ldots\ldots(6)$$

And

$$\int_{a_1}^{a_2} \delta[f(x)] dx = \sum_{i=1}^{N} \left[1 / \left| \frac{df(x)}{dx} \right|_{x_i} \right] \ldots\ldots\ldots\ldots\ldots(7)$$

In the final expression the x_i are the O's of *f* (x) between a_1 and a_2.

A delta function in three dimensions may be built as a product of three one-dimensional delta functions. In Cartesian coordinates,

$$\delta(x) = \delta(x)\delta(y)\delta(z) \ldots\ldots\ldots\ldots(8)$$

This function has the property that

$$\int d^3x f(x) \delta(x - x_0) = f(x_0) \ldots\ldots\ldots\ldots(9)$$

Returning to electrostatics, it can be seen that the charge density of a collection of point charges can be written as a sum of delta functions:

$$\rho(x) = \sum_{1=i}^{N} q_i \delta(x - x_i) \ldots\ldots\ldots\ldots\ldots(10)$$

Thus

$$E(X) = \int d^3x' \rho(x')(x - x')/|x - x'|^3$$

$$= \sum_{i=1}^{N} \int d^3x' q_i \delta(x' - x_i)(x - x')/|x - x'|^3$$

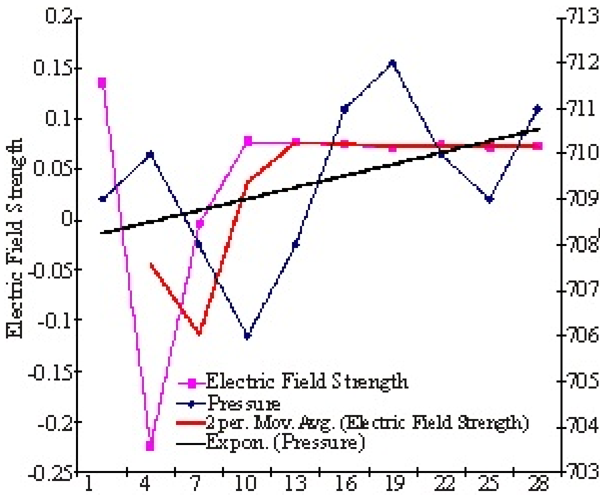
$$= \sum_{i=1}^{N} q_i (x - x_i)/|x - x_i|^3 \ldots\ldots\ldots\ldots(11)$$

$$\oint D.ds = Qens \ldots\ldots\ldots\ldots\ldots(12)$$

Measurement of Electric Field in Zaria: Modern techniques of using Data Acquisition system (DAQ), Interfaced with the modern Electrostatic field meter was utilized. The Electrostatic field meter has a very sensitive sensor to detect the presence of Electric field in an environment in KV/cm. An analogue to Digital converter (ADC) was used to convert the analogue output from the field meter to digital for the DAQ system to handle. With the DAQ system, the measured electric field strength could be monitored on the computer system along side with the time the measurement was made and the corresponding collected data logged and later exported to Microsoft Excel for onward graphical analysis of the recorded data[2,4]. The measurement was done between March (Harmattan time) and April – May (outside Harmattan time) in 2007 in the Thermodynamic laboratory of the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria. The temperature, pressure and relative humidity of the environment were recorded to determine how these environmental factors influence the measurement of the static electric field in Zaria. The recorded data from March – May, 2007 alongside with the environmental factors measured are shown in table 1

RESULTS AND DISCUSSIONS

The relative dependence of the static electric field on temperature, pressure and relative humidity as one



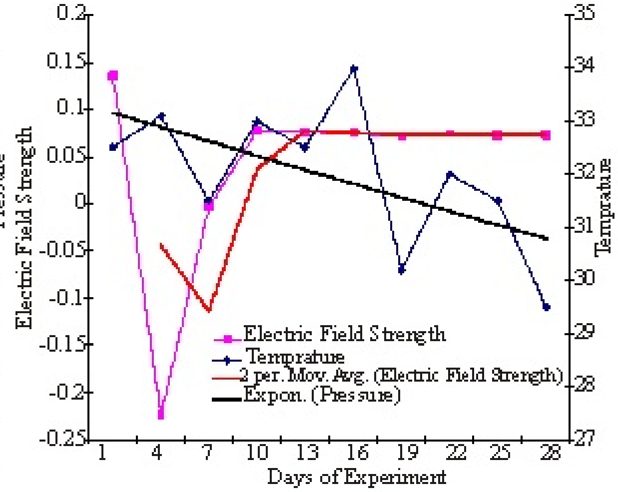
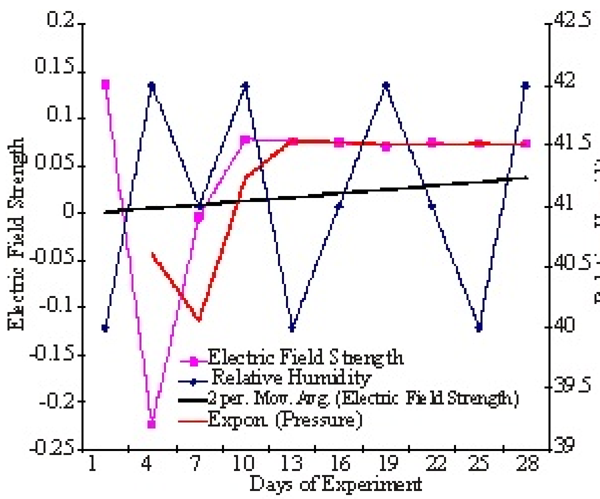


Fig. 1: Average electric field strength and pressure against days of experiment in march.
Fig. 2: Average electric field strength and temperature against days of experiment in march.



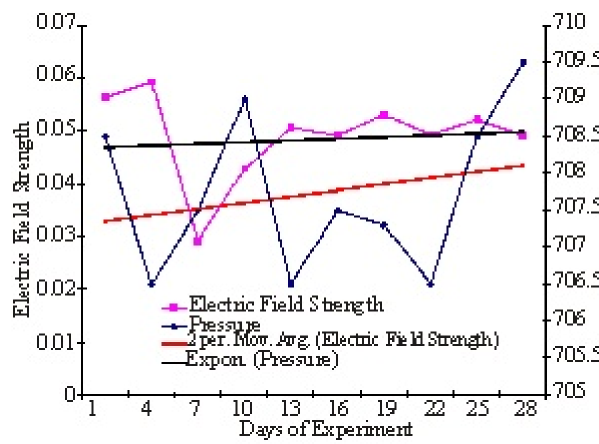
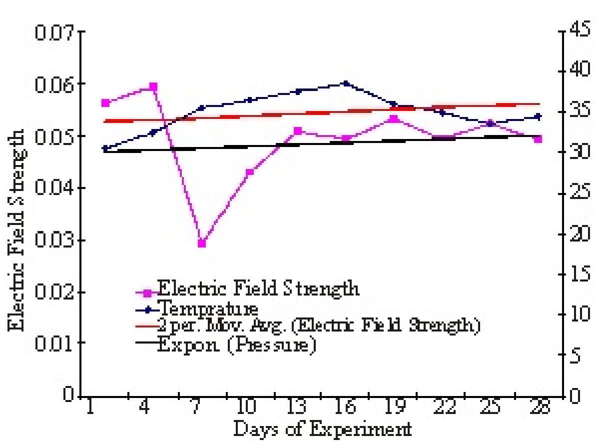


Fig. 3: Average electric field strength and relative humidity against days of experiment in march.
Fig. 4: Average electric field strength and pressure against days of experiment in April.



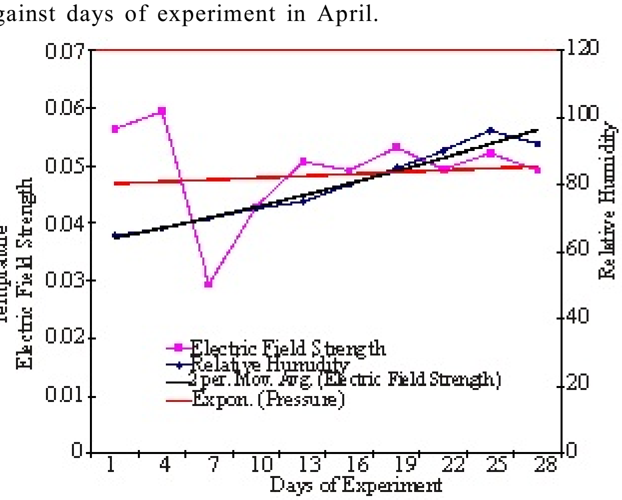
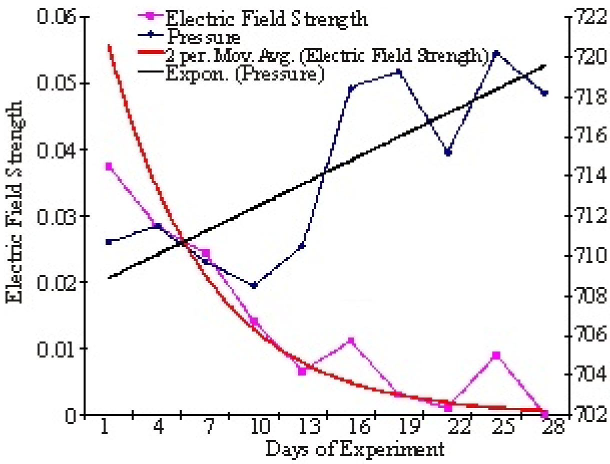


Fig. 5: Average electric field strength and temperature against days of experiment in April.
Fig. 6: Average electric field strength and relative humidity against days of experiment in April.



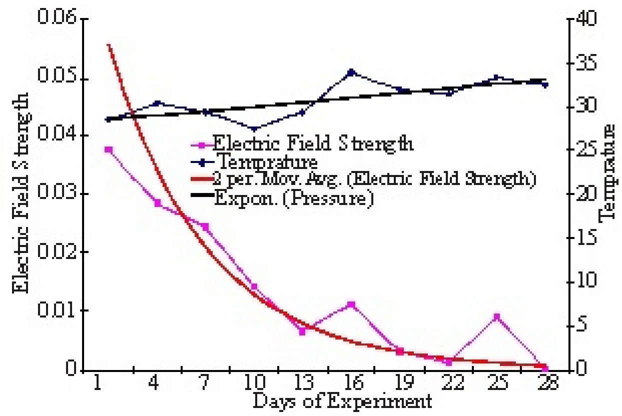


Fig. 7: Average electric field strength and pressure against days of experiment in May.
Fig. 8: Average electric field strength and temprature against days of experiment in May.

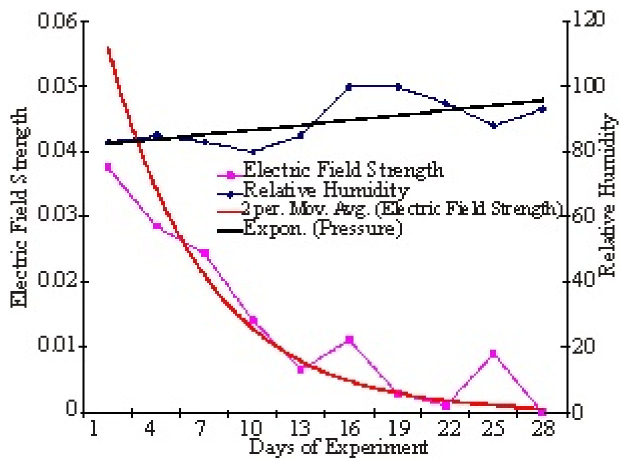
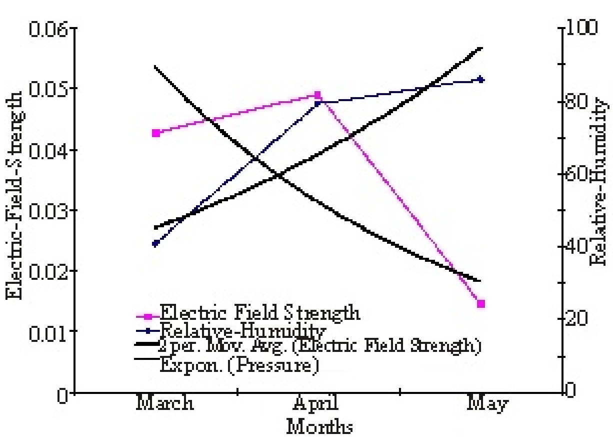


Fig. 9: Average electric field strength and relative humidity against days of experiment in May.



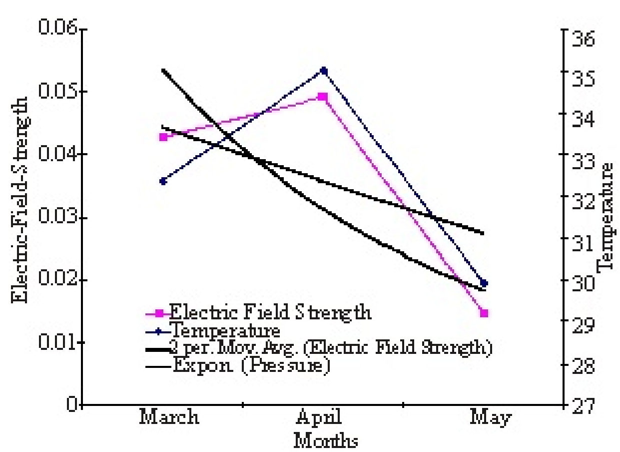


Fig. 10a: Average Electric Field Strength and relative humidity against the months (March-May).
Fig. 10b: Average Electric Field Strength and temprature against the months (March-May).

Table 1: Average measured Electric Field per day and the corresponding pressure, temperature and Relative Humidity measurement

		March		
Date	Average Electric Field Strength (kv/cm)	Relative Humidity (%)	Temperature (^{0}c)	Pressure (mmHgg)
1/3/2007	0.136392	40	32.5	709
4/3/2007	-0.2239392	42	33.1	710
7/3/2007	-0.00365184	41	31.5	708
10/3/2007	0.0776657	42	33	706
13/3/2007	0.07615051	40	32.5	708
16/3/2007	0.074409	41	34	711
19/3/2007	0.070927432	42	30.2	712
22/3/2007	0.074264529	41	32	710
25/3/2007	0.072729495	40	31.5	709
28/3/2007	0.072740175	42	29.5	711
		April		
Date	Average Electric Field Strength (kv/cm)	Relative Humidity (%)	Temperature (^{0}c)	Pressure (mmHg)
1/4/2007	0.056285094	65	30.5	708.5
4/4/2007	0.0592881	67	32.5	706.5
7/4/2007	0.02917328	70	35.5	707.5
10/4/2007	0.0428597	73	36.5	709
13/4/2007	0.050692749	75	37.5	706.5
16/4/2007	0.04919586	80	38.5	707.5
19/4/2007	0.0530777	85	36	707.3
22/4/2007	0.04936	90	35	706.5
25/4/2007	0.0521453	96	33.5	708.5
28/4/2007	0.04919586	92	34.5	709.5
		May		
Date	Average Electric Field Strength (kv/cm)	Relative Humidity (%)	Temperature ^{0}c	Pressure (mmHg)
1/5/2007	0.037571715	83	28.5	710.7
4/5/2007	0.028489689	85	30.5	711.5
7/5/2007	0.024366762	83	29.5	709.7
10/5/2007	0.014185855	80	27.5	708.5
13/5/2007	0.006590191	85	29.5	710.5
16/5/2007	0.011164614	100	34	718.5
19/5/2007	0.003008447	100	32	719.3
22/5/2007	0.00107796	95	31.5	715.2
25/5/2007	0.009047686	88	33.5	720.2
28/5/2007	0.000107614	93	32.5	718.2

From the table above, we can have the plot of the average measured electric field per day against, pressure. Temperature and Relative Humidity as shown in figures 1-9 below.

move from harmattan period to non-harmattan period could be observed from fig 1-9. from fig 10 a,b,c it could be deduced that the electric field strength decreases with decrease in temperature whereas it decreases with increase in pressure and relative humidity, as one moves from harmattan to non-harmattan period.

The measurement of static electric field in Zaria in influenced by the environmental factor such as temperature, pressure and relative humidity

Conclusion: The comparative results of the measurement of the static electric field during harmattan and outside harmattan periods show that it increases with increase in the Relative Humidity during harmattan period, but decreases with increase in the Relative Humidity outside harmattan period. Similarly, the electric field strength increase with decrease in the temperature and pressure during harmattan period but decreases with increase in temperature and pressure outside harmattan period, hence the measurement of static electric field in Zaria is influenced by the co-related environmental factors to harmattan intensities.

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