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Full Length Research Paper

Assessment of atmospheric moisture using hygroscopic salts in dry-and-wet climate of Nigeria

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Atmospheric moisture content plays an important role in climate changes studies. Atmospheric moisture content was determined using four different hygroscopic salts, viz Sodium chloride (NaCl), Potassium chloride (KCl), Zinc sulphate ($ZnSO_4$) and Magnesium chloride ($MgCl_2$) salts and hygrometer. Evaluation of different hygroscopic salts for the determination of humidity was based on the ability of the salts to absorb atmospheric moisture. The affinity of salts for atmospheric water from measured value was compared with the hygrometer measured value. Data were subjected to one-way ANOVA using the Genstat statistical package (Release 4.24 Discovery Edition) to determine the weekly average of the moisture content and bulb depression. Duncan Multiple Range Test (DMRT), T-test and a linear regression model equation was generated with the fitness within 95%. The model of the regression was tested to determine the accuracy of equation compared with wet and dry bulb thermometer depression value. Magnesium chloride ($MgCl_2$) offers the best result with significant coefficient (P = 0.01 and 0.05) and depression value of wet and dry bulb thermometer. The relative reliability of the use of hygroscopic salts in terms of accuracy of both measured and extrapolated humidity data utilization showed that these salts could be used in place of the usual hygrometer.

Key words: Hygroscopic salts, hygrometer, atmospheric moisture, humidity.

INTRODUCTION

Most studies on climate change focus on changes in temperature and precipitation neglecting the atmospheric moisture (relative humidity) which is equally very important not only because of its effect on human comfort but also because either excessively moist or excessively dry conditions can be detrimental to equipment, furniture, buildings and the like (Mitchell et al., 1995). Atmospheric water vapor is one of the most important factors in determining earth's weather and climate. It play a vital role as a greenhouse gas, as an environmental condition which influences the growth of the plants, health of man, pollution of environment (Nieuwolt, 1972) and also transpiration rate which is determined by a balance between the amount of energy available to convert water from the liquid to vapor phase and the moisture gradient. Studies have shown that humidity measurement is among the more difficult problems in basic meteorology.

In particular, the most widely used hygrometer (psychrometer) in Nigeria is not reliable (Smadi, 2006). One major problem in the use of hygrometer (psychrometer) is the use of water rather than air (which is a much less effective heat transfer medium) for hygrometers calibration (Murray, 1967). The use of water causes hygrometer to be subjected to drift consequently requiring regular recalibration. A further difficulty is that most hygrometers sense relative humidity rather than the absolute amount of water present. However, research has shown that some hygrometer works on the principle of absorbed moisture in which a known volume of gas passes over a hygroscopic or moisture-absorbing material. The use of moisture-absorbing materials has been acclaimed to be the most accurate way of measuring humidity (Jackson, 1986b). Research into the application of humidity have been extensive in nearly all the eco-climatic zones of Nigeria; however, in contrast research endeavor in humidity measurement particularly the use of hygroscopic or moisture-absorbing materials is rare. It is therefore not surprising that humidity

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Table 1. Weekly mean of hygrometer depression value and changing and non-changing salts moisture content difference.

Weeks	*NaCl	**NaCl	*KCl	**KCl	*$ZnS0_4$	**$ZnSO_4$	*$MgCl_2$	**$MgCl_2$	Hygrometer depression
1	0.87	0.988	0.678	0.83	0.662	0.706	1.272	1.19	1.2
2	0.414	0.85	0.238	0.578	0.188	1.098	2.232	2.176	2.1
3	0.762	0.248	0.29	0.182	0.476	0.178	1.844	0.726	1.8
4	0.142	0.2	0.134	0.096	0.092	0.064	1.7	0.208	1.8
5	0.152	0.166	0.11	0.11	0.086	0.008	2.052	0.208	1.8
6	0.172	0.084	0.102	0.028	0.064	0.014	1.716	0.208	2.1
7	0.362	0.15	0.2176	0.216	0.214	0.248	2.092	0.19	2.1
8	0.148	0.378	0.134	0.714	0.1	0.394	2.088	1.8	2.1

*, ** changing and non-changing salts, respectively.

measurement is restricted to the use of hygrometer (psychrometer). This study was therefore taken up to evaluate some hygroscopic salts for determining relative humidity in Abeokuta, South West Nigeria.

MATERIALS AND METHODS

Study area

This study was conducted at the meteorological station of the University of Agriculture in the Odeda area of Abeokuta in Ogun State, South-Western Nigeria. It is located 100 km north of Lagos and 80 km south-west of Ibadan and covers an area extent of 1256 km^2. The state is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated relatively with the prevalence of the moist maritime southerly monsoon from Atlantic Ocean and dry season by the continental North Easterly Harmattan winds from the Sahara desert. The area is located within a region characterized by bimodal rainfall pattern (commences in March and is plentiful in July and September, with a short dry spell in August). The long dry period extends from November to March. The annual rainfall ranges between 1400 and 1500 mm in Abeokuta and environs. The region is characterized by relatively high temperature with mean annual air temperature being about 30°C. The greatest variation in temperature is experienced in July (25.7°C) and in February (30.2°C). The humidity is lowest (37 to 54%) at the peak of dry season in February and highest at the peak of the rainy season between June and September (78 to 85%).

Determination of atmospheric moisture content

Atmospheric moisture content was determined using four different hygroscopic salts, viz Sodium Chloride (NaCl), Potassium Chloride (KCl), Zinc Sulphate ($ZnSO_4$) and Magnesium Chloride ($MgCl_2$) salt. Based on their affinity for atmospheric water, 25 g of each hygroscopic salts were weighed into 50 mm diameter beaker and stored in a container kept in a Stevenson's screen which also contained the wet and dry bulb hygrometer used as control measurement. The experiment involved salt samples which are changed weekly *NaCl, *$MgCl_2$, *$ZnSO_4$ and *$MgCl_2$; and those not changed all through the study **NaCl, **$MgCl_2$, **$ZnSO_4$ and **$MgCl_2$. There was also an overflow arrangement under every beaker.

Daily measurement was carried out for moisture adsorbed by each salt changed weekly; however those not changed were determined by weighing using digital scale and also the wet and dry bulb depression were taken. The weekly average of the moisture content and bulb depression were compared using analysis of variance, Duncan Multiple Range Test (DMRT), T-test and a linear regression model equation was generated with the fitness within 95%. The model of the regression was tested to determine the accuracy of equation compared with wet and dry bulb thermometer depression value.

RESULTS AND DISCUSSION

A comparison of four hygroscopic salts, viz Sodium chloride (NaCl), Potassium chloride (KCl), Zinc sulphate ($ZnSO_4$) and Magnesium chloride ($MgCl_2$) salts and hygrometer was made while measuring the amount of atmospheric water vapor; and this show that salts varied greatly in their ability to measure relative humidity (Table 1 and Figure 1). The amount of atmospheric water vapor varied with the hygroscopic salt used in measurement in the study area. However, the Magnesium chloride ($MgCl_2$) salt, in particular, weekly changed salt agreed closely in its relation to depression value obtained in the use of hygrometer as observed in Figure 1. This may be due to the fact that $MgCl_2$ salt has the strongest affinity for atmospheric water. The Magnesium chloride ($MgCl_2$) salt, irrespective of pattern of exposure (changed or unchanged) is in agreement to depression value obtained in the use of hygrometer. However, the unchanged $MgCl_2$ salt is closer in value to other three salts, although better than others.

Table 2 shows that there is a significant difference between the salt samples; and the depression value of wet and dry bulb from the p-value of the F statistic (0.000) is less than 5% level of significance irrespective of pattern of exposure of salts (changed of unchanged).

Duncan Multiple Range Test (DMRT) was employed to compare the salts and the depression value of wet and dry bulb (Tables 3 and 4). Table 3 shows that there is no significant difference ($P < 0.05$) between the KCl, $ZnSO_4$ and NaCl since they belong to the same category. However, the depression value of wet and dry bulb thermometer and the $MgCl_2$ moisture absorption belong to the same category since their p-value is greater than 5% level of significance. From Table 4, the non-changing salts are significantly different from the

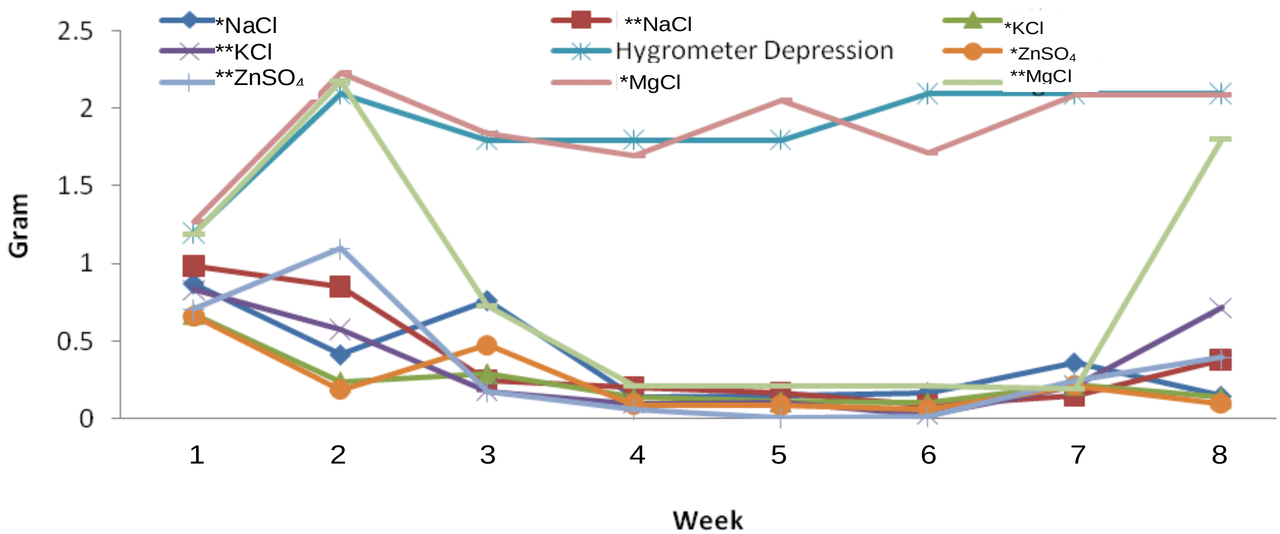

Figure 1. Weekly mean of hygrometer depression value and changing and non-changing salts moisture content difference.

Table 2. Analysis of variance for salts sample and hygrometer depression.

Parameter	Degree of freedom	P < 0.05	Result
Changing salts	199	0.000	Significant
Unchanging salts	199	0.000	Significant

Table 3. Duncan analysis of changing salts and hygrometer depression.

Changing salts	N	Subset for alpha = 0.05	
		1	2
KCl	40	0.2347	
$ZnSO_4$	40	0.2875	
NaCl	40	0.3778	
Standard difference	40		1.8625
$MgCl_2$	40		1.8785
Significance		0.232	0.887

Means for groups in homogeneous subsets are displayed.

Table 4. Duncan test for unchanging salts and hygrometer depression.

Non changing salts	N	Subset for alpha = 0.05	
		1	2
$ZnSO_4$	40	0.3347	
KCl	40	0.3378	
NaCl	40	0.3830	
$MgCl_2$	40	0.6348	
Standard difference	40		1.8625
Significance		0.057	1.000

Means for groups in homogeneous subsets are displayed.

Table 5. Correlation test between the changing $MgCl_2$ and depression of hygrometer.

Parameter	Correlation	Standard difference	Magnesium chloride salt
Depression value	Pearson correlation	1	0.993
	Significance (2-tailed)		0.000
	N	40	40
Magnesium chloride salt	Pearson correlation	0.993	1
	Significance (2-tailed)	0.000	
	N	40	40

** Correlation is significant at the 0.01 level (2-tailed).

Table 6. T-test between the changing $MgCl_2$ and hygrometer depression. Paired samples (a) test (b) correlations and (c) statistics.

(a) Paired samples test

Model		Paired differences					t	df	Significance (2-tailed)
		Mean	Standard deviation	Standard error mean	95% Confidence Interval of the difference				
					Lower	Upper			
Pair 1	Magnesium chloride – depression	0.01385	0.08216	0.01316	-0.01279	0.04048	1.052	38	0.299

(b) Paired samples correlations

		N	Correlation	Significance
Pair 1	Magnesium chloride and depression	39	0.993	0.000

(c) Paired samples statistics

		Mean	N	Standard deviation	Standard error mean
Pair 1	Magnesium chloride	1.8728	39	0.65198	0.10440
	Depression	1.8590	39	0.67812	0.10859

standard difference.

Generally, the Magnesium chloride ($MgCl_2$) salt, showed more reliable estimate of relative humidity than the other three salts. Since it was observed that there is a link between the changing $MgCl_2$ and depression value of wet and dry bulb thermometer, correlation test was carried out between the variables and presented in Table 5.

The correlation between the $MgCl_2$ and the standard difference is 0.993 meaning that there is a positive correlation between the variables.

Table 6 shows paired sample T-test of changing $MgCl_2$ and depression of hygrometer. It was observed that there is no significant difference between the $MgCl_2$ moisture content value and hygrometer depression; since the p-value is greater than 5% level of significance we say that there is no significant difference between the $MgCl_2$ and depression.

Table 7a and b shows linear regression model for changing $MgCl_2$ and depression of hygrometer from the coefficient table. The linear regression equation is given as:

$$Y = -.076 + 1.032X$$

Where Y = Depression value of wet and dry bulb thermometer. X = Magnesium chloride salt moisture content.

Test of linearity

Since the p–value of t–statistic (0.000) is less than 5% level of significance used for this analysis, we say that the coefficient is significant in the model and contribute to the model (Table 7b).

From Table 8, it was observed that the independent variable explained the variation in the dependent variable as the p–value of the F-statistic (0.000) is less than 5% level of significance used for the analysis. From the model summary table, the R^2 model is 0.986 meaning that the model is 98.6% fit and it is a very good model.

Test running the model equation

With the linear regression equation being generated,

Table 7. Linear regression model for changing $MgCl_2$ and depression of hygrometer (a) Coefficients (b) ANOVA.

(a) Coefficients (Dependent variable: standard difference)						
Model		Unstandardized coefficients		Standardized coefficients	T	Significance
		B	Standard error	Beta		
1	Constant	-0.076	0.040		-1.899	0.065
	Magnesium chloride salt	1.032	0.020	0.993	51.457	0.000

(b) ANOVA (Dependent variable: standard difference)						
Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	17.246	1	17.246	2.648E3	0.000[a]
	Residual	0.248	38	0.007		
	Total	17.494	39			

[a] Predictors: (Constant), Magnesium chloride salt.

Table 8. Model summary for changing $MgCl_2$ and depression of hygrometer.

Model	R	R^2	Adjusted R^2	Standard error of the estimate
1	0.993[a]	0.986	0.985	0.08070

[a] Predictors: (Constant), Magnesium chloride salt.

Table 9. Showing linear model equation result after substituting for $MgCl_2$ value (Y = -0.076 + 1.032 X).

Days	Value of morning and afternoon difference in $MgCl_2$ readings	Depression value of wet and dry bulb thermometer	Linear regression equation result
1	1.86	2.0	1.84
2	2.62	2.5	2.63
3	3.87	4.0	3.92
4	2.33	2.5	2.33

this prompted a four days observation back to the field to collect data for $MgCl_2$ to be input in the equation and compared with the depression value of wet and dry bulb thermometer result being taken on same days of second visit to the field. It could be observed from Table 9 that the result of the linear regression equation after substituting for the value of $MgCl_2$ in the equation gave an approximate value of the depression value of wet and dry bulb thermometer.

Conclusion

In the study area characterized by an irregular sequence of relative humidity which varies with lowest (37 to 54%) at the peak of dry season in February and highest (78 to 85%) at the peak of the rainy season between June and September (Bello, 1997), it was concluded that, where the use of wet and dry bulb hygrometer is not available or needs to be tested, the use of hygroscopic salt particularly Magnesium chloride ($MgCl_2$) offers comparatively desirable result. However, the reliability of results from hygroscopic salts considered depends on replacement of salts at interval and the personnel. Where the bulk of data are obtained by extrapolation from an unchanged salt a less reliable result can be expected.

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