A Study of Weather Related Respiratory Diseases in Eco-climatic Zones

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We study the temporal pattern of selected respiratory diseases and the influence of specific weather parameters on their morbidity in two eco-climatic zones in Nigeria for the period 1996- 2006. Out of 2,056 and 2,647 cases of respiratory diseases (bronchial asthma, bronchopneumonia, lobar pneumonia, bronchiolitis, cardiac asthma, pulmonary tuberculosis, sinusitis, tonsillitis and upper respiratory tract infection) reported in Humid-forest (Ile-Ife) and Derived-savanna (Ilorin), respectively, 60% and 48% for each region respectively occurred in subjects of age less than ten years. Whereas, for patients aged 80 years and above it accounted for 1.2% and 1.7% in respective zones. There is a significant ($p<0.01$) variation in the morbidity pattern of respiratory diseases among age groups at each location. Males in humid forest and derived savanna reported respectively about 56.7% and 59.0% of the specific respiratory diseases. Out of all the respiratory diseases considered, bronchial asthma, lobar pneumonia, sinusitis and tonsillitis are statistically significant with weather variables in humid forest (Ile-Ife) while bronchial asthma, bronchopneumonia, cardiac asthma and lobar pneumonia are statistically significant with maximum air temperature ($p < 0.05$) in derived savanna (Ilorin). Further analysis showed that maximum air temperature accounted for 46.6% ($r=0.68$) and 43.3% ($r=0.66$) of bronchial asthma ($p< 0.05$) at humid forest and derived savanna, respectively. Similarly, air temperature explained 39.1%, 39.8% and 43.8% of bronchopneumonia, cardiac asthma and lobar pneumonia occurrence in derived savanna respectively. Relative humidity accounted for 36.3% of tonsillitis morbidity and in combination with wind speed, explained 82.1% of lobar pneumonia in humid forest. Maximum temperature and wind speed accounted for 69.3% of the occurrence of sinusitis at humid forest. The study advocates the importance of inclusion of thermal environment into monitoring and surveillance of respiratory diseases transmission.

1. Introduction

All climate and weather variables have some influence on human health [1-4]. The effect may be either directly on the human body or indirectly through effects on disease-causing organism or their vectors [5-7].

The effects of high temperatures on human health are modified by the amount of moisture in the air. The degrees to which thermo-regulatory mechanisms must operate to keep body temperature normally vary with humidity. Human comfort is therefore affected by humidity. Certain levels of humidity are ideally suited to the survival and reproduction of pathogens such as bacteria, viruses, parasites, and their vectors [6-8].

Precipitation leads to increased humidity with consequent effects on humans [9] and cold weather adds to chilling of human body, thereby making it more susceptible to disease or it aggravating chronic diseases. Depending on the amount and timing, it may modify the ecological habitat of parasites, their hosts, and insect vectors such that their growth and survival are affected.

Abrupt changes in weather, such as those associated with the passage of a weather fronts, have been implicated in human discomfort with symptoms such as headache. Moreover, there is evidence that weather changes may be related to the onset of some diseases, such as common colds and upper respiratory tract infection. Wind in combination with temperature and humidity can affect human thermo-regulation. It can also be a means of spreading the causative agents of disease, insect vectors and allergens [9, 10].

With climate change, the micro-environment, particularly the temperature in which humans live changes, thereby altering the physiological

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adaptability of human body to the environment. For the human body to function properly, the internal body temperature must be kept in a constant range of about 37.0^0C to 37.5^0C. In Nigeria for instance, given the low level of medical care and standard of living, all climate-change related extreme events are likely to impact human health seriously. In addition, the low standard of living itself contributes to higher impact of climate change on human health [11].

Respiratory diseases are one of the most ancient and well-documented in both advanced and developing nations. In the United States, an estimated 46.9 million persons have respiratory diseases [12-14] which accounted for nearly forty percent of all deaths in 1990 [15, 16] and in the same year the direct costs of health care services and indirect costs through loss of productivity was put at about $104 billion[17, 18]. In 1992, respiratory diseases top the list of fatal diseases [15, 16] in Peru. Similarly in Nigeria, respiratory related ailments were ranked among the leading diseases in the year 1994 to 1997 [19-22]. Today, respiratory diseases remains common throughout the world, as half of the world's population is infected with one respiratory disease or the other [23-25].

Respiratory disorders are typically caused by allergic reaction, infection, or inhalation of dusts or chemicals, and may be influenced by weather and climate, either directly via sudden drops in temperature or indirectly via an increase in pollutant levels. The aim of this paper is to analyse temporal, spatial and seasonal transmission of selected respiratory diseases with respect to thermal environment in order to ascertain the role of meteorological variables in the transmission and to determine the threshold for its occurrence by using bio-meteorological parameters.

2. Data and Methods

The two locations for this study are Ile-Ife (7^0 30' N and 4^0 31' E) which is situated in the South-western humid forest zone of Nigeria and Ilorin (8^0 30' N and 4^0 35' E) which is situated in the derived savanna zone of Nigeria (Figure 1). Ile-Ife has an annual rainfall which exceeds 1500mm, which covers March to November with average relative humidly of about 55% during the dry season and about 90% during the rainy season. The mean daily maximum air temperatures range from 27^0C to 33^0C, while the mean daily minimum air temperatures range from 15^0C to 23^0C. Ilorin has average annual rainfall of about 1200mm, which covers the months of April to October. The relative humidity ranges from 70% to 80% during the rainy season while that of dry season is between 38% and 50%. The mean daily maximum air temperatures range from 29^0C to 37^0C, while the mean daily minimum air temperature 20^0C to 25^0C [26].

The sources of data for the categories of respiratory diseases (Table 1) according to International Classification of Diseases, ICD-10 [27] for the period 1996 to 2006 used in this study is from the diagnostic index card (DIC) of patients at the Obafemi Awolowo University Teaching Hospital, Ile-Ife for humid forest zone and University of Ilorin Teaching Hospital, Ilorin for derived savanna zone for the period 1996 to 2006. The specific information retrieved from the records of patients after permission has been granted by the Ethical committee of each hospital were age, sex, months and year of reporting of the diseases.

The limitation of this data is due to two main reasons: First, not everybody goes to hospital for treatment because of financial constraint. Second, there are patients who prefer private hospital to government hospital. Moreover, there are others who use other methods such as traditional herbal medicine and spiritual means for the treatment of their ailments. The information therefore may not represent the true number of respiratory cases in each of the two eco-climatic zones used for this study. At the same time, the data were not regarded as worthless; rather it is believed that they at least depict a general pattern of respiratory diseases occurrence in the study area.

Meteorological data, monthly rainfall (mm), minimum and maximum air temperature (^{0}C), relative humidity (%), and wind speed (ms^{-1}) for 1996 to 2006 for the two eco-climatic zones were collected from the Nigerian Meteorological Agency, Lagos. This agency is the official organization charged with the responsibilities of collecting, collating and documenting weather data, among other thing in Nigeria.

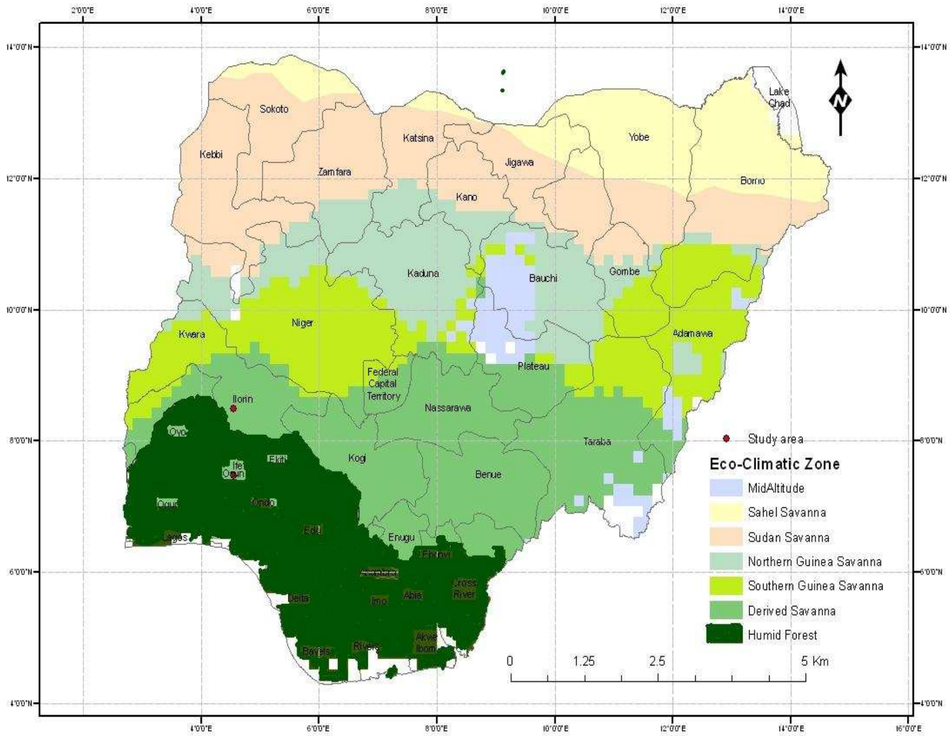

Fig.1: Map of Nigeria showing eco-climatic zones of Nigeria and study areas
Source: International Institute of Tropical Agriculture (2005)

Table 1: Categories of respiratory diseases.

RESPIRATORY DISEASE	*ICD NO*	**DIC CODE**
Upper Respiratory Tract Infection (URTI)	J06.9	465.9
Bronchopneumonia (BP)	J18.0	485
Lobar Pneumonia (LP)	J18.1	481
Tonsillitis (TSL)	J03	487.1
Pulmonary Tuberculosis (PTB)	J44.9	011.9
Bronchial Asthma (BA)	J45.9	493.9
Cardiac Asthma (CA)	J46	493.1
Bronchiolitis (BR)	J21	466.1
Sinusitis (ST)	J32	473.9

Source: International Classification of Diseases, ICD-10 [27]

The methods used for data analysis in this study, include descriptive and inferential statistics. Simple descriptive and quantitative analyses were employed to compute the monthly, seasonal and annual trends of the selected respiratory diseases. This involves the use of average to determine trends across years and four seasonal groups namely: Early Dry (ED, October to December), Late Dry (LD, January to March), Early Wet (EW, April to June) and Late Wet (LW, July to September) though this seasonal grouping might not actually satisfied the seasonal pattern of the atmospheric weather system of the study areas. Also, graphical representation was used to depict the possible modulation effects of climatic factors on annual and monthly trends of respiratory diseases. Morbidity cases of respiratory diseases on annual and monthly bases for eleven years (1992 – 2002) for males and females under the following age groups: 0 – 9, 10 – 19, 20 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69, 70 – 79 and 80 years and above were analyzed.

Moreover, the correlation statistic was employed to examine the relationship between rainfall, relative humidity, wind speed, maximum temperature and minimum temperature and specific respiratory diseases. In order to identify the specific parameter that explains the temporal pattern of the respiratory diseases; step wise multiple regression analysis was conducted.

3. Stepwise Multiple Regression

Multiple regression is most often used in the case that response variable may depend on more than one explanatory variables, sometime it is called extended linear model. The multiple regression equation having more than two explanatory factors is given below:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \dots + b_nX_n$$

The dependent variable, Y (monthly value of different categories of respiratory diseases) and independent variables X_1, X_2, X_3, ... X_n, (meteorological parameters) was regressed using the above equation; b_0 is the interception coefficient; b_1, b_2, b_3, b_4, ... are linear effect parameters or coefficients. Coefficients of this equation were estimated from the experimental results with SPSS 13.0. A regression model is considered to be statistically significant if the calculated F value is larger than F distribution value at a probability of α.

The analysis of variance (ANOVA) included F-test, p-value of the models and determination coefficient R^2, which measures the goodness of fit of regression model at a confidence limit of 95% were performed. The larger the magnitude of t-values and the smaller the magnitude of p-values, the more significant is the corresponding coefficient [28-30].

4. Results

Out of the 2,056 cases of respiratory diseases reported at Ile-Ife within the study period, bronchopneumonia accounted for 45.8% (Table 2). The next in order of magnitude was lobar pneumonia (18.0%), pulmonary tuberculosis (14.2%) and bronchial asthma (11.6%). These four respiratory diseases jointly accounted for 89.6% of all the diseases. The cases of upper respiratory tract infection, tonsillitis, cardiac asthma and sinusitis were fewer (less than 11.0%). The age group that recorded the highest percentage in each respiratory disease were bronchial asthma, tonsillitis and upper respiratory tract infection (<10 years), lobar pneumonia (10 – 19 years), pulmonary tuberculosis and sinusitis (20 – 29 years) and cardiac asthma (60 – 69 years). There is a significant variation in the occurrence of the respiratory diseases among the age group (0.01 probability level).

The profile of respiratory diseases in Ilorin (Table 3) is similar to that of Ile-Ife, except for the percentage contribution of each respiratory disease. Bronchopneumonia was the most common (29.9%), followed by lobar pneumonia (23.6%), pulmonary tuberculosis (21.2%) and bronchial asthma (13.5%). About 48% of the 2,647 cases were found among patients less than ten years, while the least number of cases occurred among patients 80 years and above (1.7%). The age group less than ten years recorded the highest percentage in the following respiratory diseases: bronchial asthma, bronchopneumonia, bronchiolitis, lobar pneumonia and upper respiratory tract infection. It is only pulmonary tuberculosis and sinusitis that recorded the highest cases among patients aged between 20 and 29 years, similar to that of Ile-Ife location.

Table 2: Age characteristics of respiratory diseases patients in humid forest zone (Ile-Ife).

Specific Respiratory Diseases	<10 years	10 – 19 years	20 – 29 years	30 – 39 years	40 – 49 years	50 – 59 years	60 – 69 years	70 – 79 years	80 years and above	Total
Bronchial Asthma	109(5.3%)	25(1.2%)	28(1.3%)	16(0.7%)	25(1.2%)	13(0.6%)	11(0.5%)	9(0.4%)	4(0.2 %)	240(11.6%)
Bronchopneumonia	843(41.0%)	25(1.2%)	9(0.4%)	7(0.3%)	6(0.2%)	6(0.2%)	25(1.2%)	12(0.5%)	10(0.5%)	943(45.8%)
Bronchiolitis	17(0.8%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0.0%)	17(0.8%)
Cardiac Asthma	3(0.1%)	2(0.0%)	4(0.1%)	3(0.1%)	5(0.2%)	5(0.2%)	7(0.3%)	3(0.2%)	2(0.1%)	34(1.6%)
Lobar Pneumonia	80(3.8%)	82(3.9%)	74(3.5%)	53(2.5%)	31(1.5%)	24(1.1%)	15(0.7%)	9(0.4%)	4(0.2%)	372(18.1%)
Pulmonary tuberculosis	37(1.7%)	33(1.6%)	56(2.7%)	45(2.1%)	42(2.0%)	29(1.4%)	32(1.5%)	13(0.6%)	5(0.2%)	292(14.2%)
Sinusitis	5(0.2%)	4(0.1%)	7(0.3%)	2(0.1%)	3(0.1%)	2(0.1%)	2(0.1%)	0(0%)	0(0%)	25(1.2%)
Tonsillitis	22(1.0%)	6(0.2%)	3(0.1%)	4(0.1%)	2(0.1%)	1(0.5%)	0(0%)	0(0%)	0(0%)	38(1.8%)
Upper Respiratory tract infection	81(3.9%)	5(0.2%)	3(0.1%)	4(0.1%)	1(0.1%)	0(0%)	0(0%)	1(0.1%)	0(0%)	95(4.6%)
All Respiratory Diseases	1197 (58.2%)	182 (8.8%)	184 (8.9%)	134 (6.5%)	115 (5.5%)	80 (3.8%)	92 (4.4%)	47 (2.2%)	25 (1.2%)	2056 (100%)
Coefficient of Variation	19.1%	12.2%	12.5%	12.6%	11.5%	11.1%	10.9%	9.9%	11.4%	

Table 3: Age characteristics of respiratory diseases patients in derived savanna zone (Ilorin).

Specific Respiratory Diseases	<10 years	10 – 19 years	20 – 29 years	30 – 39 years	40 – 49 years	50 – 59 years	60 – 69 years	70 – 79 years	80 years and above	Total
Bronchial Asthma	143 (5.4%)	40 (1.5%)	47 (1.7%)	32 (1.2%)	33 (1.2%)	20 (0.7%)	24 (0.9%)	12 (0.4%)	8 (0.3%)	359 (13.5%)
Bronchopneumonia	688 (25.9%)	37 (1.4%)	16 (0.6%)	7 (0.3%)	11(0.4%)	6 (0.2%)	10 (0.3%)	9(0.3%)	9 (0.3%)	793 (29.9%)
Bronchiolitis	63 (2.3%)	1(0.1%)	4 (0.2%)	3 (0.1%)	0 (0%)	2 (0.1%)	1(0.1%)	2 (0.1%)	0 (0.0%)	76 (2.0%)
Cardiac Asthma	14 (0.5%)	4 (0.2%)	7 (0.3%)	5 (0.2%)	10 (0.4%)	3 (0.1%)	5 (0.2%)	4 (0.2%)	2 (0.1%)	54 (2.0%)
Lobar Pneumonia	16 9 (6.3%)	119 (4.5%)	116 (4.4%)	65 (2.4%)	35 (1.3%)	38 (1.4%)	46 (1.7%)	22 (0.8%)	17 (0.6%)	627 (23.6%)
Pulmonary tuberculosis	67 (2.5%)	64 (2.5%)	139 (5.2%)	117 (4.4%)	49 (1.8%	51(1.9%)	49 (1.8%)	16 (0.6%)	10 (0.4%)	562 (21.2%)
Sinusitis	0 (0%)	1(0.1%)	3 (0.1%)	2 (0.12%)	1 (0.1%)	1(0.1%)	0 (0%)	1 (0.1%)	0 (0%)	9 (0.3%)
Tonsillitis	21(0.7%)	9 (0.3%)	4 (0.2%)	1(0.1%)	1(0.1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	36 (1.3%)
Upper Respiratory tract infection	94 (3.5%)	13 (0.5%)	14 (0.5%)	4 (0.2%)	1(0.1%)	5 (0.2%)	0 (0%)	0 (0%)	0 (0%)	131 (4.9%)
All Respiratory Diseases	1259 (47.5%)	288 (10.8%)	350 (13.2%)	236 (8.9%)	141 (5.3%)	126 (4.7%)	135 (5.1%)	66 (2.4%)	46 (1.7%)	2647 (100%)
Coefficient of Variation	14.4%	2.6%	11.1%	14.4%	11.1%	12.5%	12.5%	10.3%	11.4%	

Table 4 shows the distribution of respiratory diseases according to gender of patients in humid forest zone (Ile-Ife) and derived savanna zone (Ilorin). In Ile-Ife, out of the 2,056 cases recorded within the study period, 56.7% were males while females accounted for the remaining percent. In each of the specific respiratory diseases, males accounted for higher percentage of bronchiolitis (70.6%), upper respiratory tract infection (63.2%), lobar pneumonia (61.3%), tonsillitis (57.9%), pulmonary tuberculosis (56.5%), bronchopneumonia (56.2%), sinusitis (52.0%), bronchial asthma (50.4%) cases. Females accounted for higher percentage only in cardiac asthma (52.9%). There is a significant variation in the occurrence of these diseases between the two sex groups ($\chi^2 = 69.34$; $p < 0.01$) in Ile-Ife.

In Ilorin, out of 2,647 cases reported within the study period, 41% were females and 59% males. Males accounted for higher percentage in lobar pneumonia (63.5%), bronchiolitis (63.2%), pulmonary tuberculosis (59.4%), bronchopneumonia (58.8%), cardiac asthma (57.4%), tonsillitis (55.6%) and bronchial asthma (54.3%), while females accounted for higher percentage in the occurrence of sinusitis (55.6%) and upper respiratory tract infection (50.4%). There is no significant difference in the reported cases of the diseases between sex groups in Ilorin.

Table 4: Gender characteristics of Respiratory Diseases patients (Ile-Ife and Ilorin).

Respiratory Disease	*Female (Ile-Ife)*	*Male (Ile-Ife)*	*Total (Ile-Ife)*	*Female (Ilorin)*	*Male (Ilorin)*	**Total (Ilorin)**
Bronchial asthma	119 (49.6%)	121 (50.4%)	240	164 (45.7%)	195 (54.3%)	359
Bronchopneumonia	413 (43.8%)	530 (56.2%)	943	327 (41.2%)	466 (58.8%)	793
Bronchiolitis	5 (29.4%)	12 (70.6%)	17	28 (36.8%)	48 (63.2%)	76
Cardiac asthma	18 (52.9%)	16 (47.1%)	34	23 (42.6%)	31 (57.4%)	54
Lobar pneumonia	144 (38.7%)	228 (61.3%)	372	229 (36.5%)	398 (63.5%)	627
Pulmonary tuberculosis	127 (43.5%)	165 (56.5%)	292	228 (40.6%)	334 (59.4%)	562
Sinusitis	12 (48.0%)	13 (52.0%)	25	5 (55.6%)	4 (44.4%)	9
Tonsillitis	16 (42.1%)	22 (57.9%)	38	16 (44.4%)	20 (55.6%)	36
Upper Respiratory Tract Infection	35 (36.8%)	60 (63.2%)	95	66 (50.4%)	65 (49.6%)	131
All Respiratory Diseases	889 (43.2%)	1167 (56.8%)	2056 (100%)	1086 (41.0%)	1561 (59.0%)	2647 (100%)

Fig. 2 and Fig. 3 show the annual trend of selected respiratory diseases in the humid-forest zone (Ile-Ife) and the derived savanna zone (Ilorin). The results showed that the magnitude of occurrence of different categories of respiratory diseases differs, the highest reported cases is bronchopneumonia (46% – Ile-Ife) and (30% – Ilorin) followed by lobar pneumonia (18% – Ile-Ife) and (24% – Ilorin) in both eco-climatic zones. The least reported case is bronchiolitis (0.83% – Ile-Ife) in humid forest zone while sinusitis (0.34% – Ilorin) is the least reported case in the derived savanna zone. With respect to all the categories of respiratory diseases, the year 1999 recorded the highest reported cases (342 patients) while 1997 had the least number (77 patients) at Ile-Ife (humid forest). At Ilorin (derived savanna), the highest value of reported respiratory diseases occurred in 1996 (338 patients) while the least cases occurred in 2006 (63 patients).

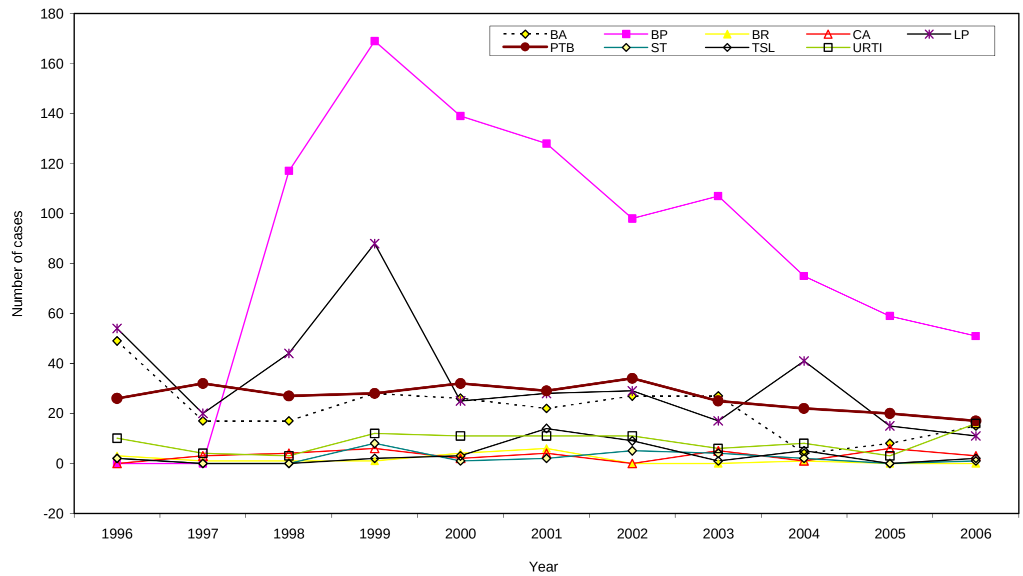

Fig. 2: Annual trends of selected respiratory diseases in humid forest zone (Ile-Ife), Nigeria

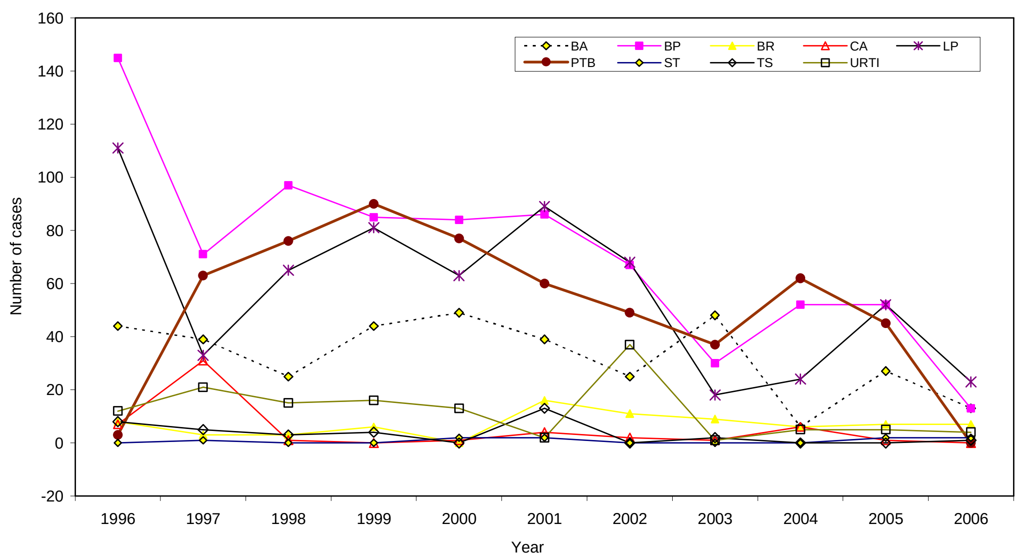

Fig. 3: Annual trends of selected respiratory diseases in derived savanna zone (Ilorin), Nigeria

Table 5 shows the coefficient of correlation between selected respiratory diseases and weather parameters in humid forest (Ile-Ife) and derived savanna (Ilorin). In Table 5, only meteorological variables that are significantly correlated with the selected respiratory diseases are shown. In Ile-Ife, there is negative correlation between bronchial asthma and maximum temperature and also relative humidity at 0.05 probability level. On the contrast, it shows positive correlation between lobar pneumonia, maximum temperature and wind speed; but negative correlation with relative humidity at the 0.05 and 0.01 probability levels. Also, significant positive correlation exists between sinusitis and, maximum temperature and wind speed. Tonsillitis has negative correlation with relative humidity at the 0.05 probability level. While other respiratory diseases, such as, bronchopneumonia, bronchiolitis, cardiac asthma, pulmonary tuberculosis and upper respiratory tract infection are not significantly correlated with any of the weather parameters.

In Ilorin, bronchial asthma, broncho-pneumonia and cardiac asthma have negative correlation with maximum temperature at 0.05 probability level. There is also a significant correlation between lobar pneumonia and maximum temperature at 0.05 probability level. Other respiratory diseases, such as, pulmonary tuberculosis, bronchiolitis, sinusitis, tonsillitis and upper respiratory tract infection are not significantly correlated with any of the weather parameters in derived savanna (Ilorin) zone.

Table 5: Coefficient of correlation between selected respiratory diseases and weather parameters in humid forest zone (Ile-Ife) and derived savanna zone (Ilorin).

Respiratory Disease	*Max. Temp. (Ile-Ife)*	*Relative Humidity (Ile-Ife)*	*Wind Speed (Ile-Ife)*	**Max. Temp. (Ilorin)**
Bronchial asthma	-0.678*	0.610*	-.0131	-0.658 *
Bronchopneumonia	-0.560	0.453	-0.198	-0.631 *
Bronchiolitis	-0.351	0.305	-0.249	-0.346
Cardiac asthma	0.002	0.020	-0.522	-0.625*
Lobar pneumonia	0.707*	-0.754**	0.560*	0.662*
Pulmonary tuberculosis	-0.283	0.190	0.503	-0.233
Sinusitis	0.671*	-0.524	0.587*	-0.108
Tonsillitis	0.564	-0.603*	-0.019	0.162
Upper respiratory tact infection	0.191	-0.308	-0.150	-0.543

** - Correlation is significant at the 0.01 probability level
* - Correlation is significant at the 0.05 probability level

Table 6 presents the regression model between selected respiratory diseases and weather parameters in humid forest zone (Ile-Ife) and derived savanna zone (Ilorin). The result of the analysis shows that maximum temperature and relative humidity accounted for 46.5% (R^2 = 0.465) of the temporal pattern of bronchial asthma at 0.05 probability level in Ile-Ife.

Relative humidity, wind speed and maximum temperature accounted for 82.3% of the temporal pattern of lobar pneumonia occurrence. Specifically, relative humidity accounted for 56.8% (R^2 = 0.568) of the total occurrence; next to it is wind speed, which explained 23.2% (R^2 = 0.232) and maximum temperature, 0.2% (R^2 = 0.002) of the lobar pneumonia occurrence.

Regression model of sinusitis on maximum temperature and wind speed is significant at the 0.05 probability level. Maximum temperature and wind speed contributed 45% (R^2 = 0.45) and 24.3% (R^2 = 0.243) to the occurrence of sinusitis respectively.

Relative humidity accounted for 36.3% (R^2 = 0.363) of the temporal pattern of tonsillitis occurrence at 0.05 probability level.

Meanwhile, in Ilorin, maximum temperature accounted for 43.8% (R^2 = 0.438) of the temporal pattern of lobar pneumonia occurrence at 0.05 probability level. It also accounted for 43.3% (R^2 = 0.433) of the temporal pattern of bronchial asthma occurrence at 0.05 probability level.

Furthermore, maximum temperature accounted for 39.8% (R^2 = 0.398) and 39.1% (R^2 = 0.391) of the temporal pattern of bronchopneumonia occurrence and cardiac asthma occurrence at 0.05 probability level.

From the above result, maximum temperature, relative humidity and wind speed are the weather parameters that play significant roles in the occurrence of respiratory diseases in humid forest zone (Ile-Ife), while maximum temperature is the only weather parameters that play significant role in the occurrence of respiratory diseases in derived savanna zone (Ilorin).

Table 6: Summary of Regression between selected respiratory diseases and weather. Parameters in humid forest zone (Ile-Ife) and derived savanna zone (Ilorin).

Study areas	*Dependent Variables*	*Independent Variables*	*R*	*R^2*	*Adjusted R^2*	*Std. Error*	*R^2 Change*	*F change*	**Significant F^2 change**
Ile-Ife	Bronchial Asthma	Maximum temperature &	0.682	0.465	0.411	5.61	0.465	8.682	0.015
		Relative Humidity	0.682	0.465	0.346	5.91	0.465	8.210	0.016
	Lobar pneumonia	Relative humidity,	0.754	0.568	0.525	12.27	0.568	13.167	0.005
		Wind speed &	0.894	0.800	0.755	8.81	0.250	12.650	0.006
		Maximum temperature	0.895	0.802	0.728	9.30	0.110	12.152	0.007
	Sinusitis	Maximum temperature &	0.671	0.450	0.395	2.08	0.450	8.188	0.017
		Wind Speed	0.833	0.693	0.625	1.64	0.243	7.142	0.026
	Tonsillitis	Relative Humidity	0.603	0.363	0.300	2.19	0.363	5.707	0.038
Ilorin									
	Bronchial Asthma	Maximum temperature	0.658	0.433	0.376	11.85	0.433	7.633	0.020
	Broncho-pneumonia	Maximum temperature	0.631	0.398	0.338	17.63	0.398	6.611	0.028
	Cardiac Asthma	Maximum temperature	0.625	0.391	0.330	1.83	0.391	6.412	0.30
	Lobar Pneumonia	Maximum temperature	0.662	0.438	0.382	22.04	0.438	7.800	0.019

The predictive equations involving all the critical weather parameters and the specific respiratory diseases for the two locations used for this study are given below:

The predictive equations for humid forest zone (Ile – Ife):

$$^{H}Y_{BA} = 78.2170 - 1.8790X_{T} - 0.0127X_{RH}$$

$$^{H}Y_{LP} = 98.3250 + 0.7320X_{T} + 10.9570X_{W} - 1.5710X_{RH}$$

$$^{H}Y_{ST} = 0.7390X_{T} + 1.6460X_{W} - 29.9260$$

$$^{H}Y_{TSL} = 18.9160 - 0.1926X_{RH}$$

The predictive equations for derived savanna zone (Ilorin):

$$^{S}Y_{BA} = 157.5100 - 4.4107X_{T}$$

$$^{S}Y_{BP} = 250.9500 - 6.3881X_{T}$$

$$^{S}Y_{LP} = 9.1964X_{T} - 214.1200$$

$$^{S}Y_{CA} = 21.8790 - 0.6000X_{T}$$

Where, Y_{BA} represents the values of bronchial asthma, Y_{BP} represents the values of bronchopneumonia, Y_{LP} represents the values of lobar pneumonia, Y_{CA} represents the values of cardiac asthma, Y_{TSL} represents the values of tonsillitis, Y_{ST} represents the values of sinusitis, X_T denotes the values of mean maximum temperature, X_{RH} denotes the values of mean relative humidity, X_W denotes the values of mean wind speed, superscript S mean derived savanna zone and superscript H mean humid forest zone.

The analysis of this study (Fig. 4) showed that high occurrence of bronchial asthma is associated with maximum air temperature ranges between 26.0^0C and 28.0^0C and relative humidity of 87% to 91% (Fig. 5) in the months of June to October in humid forest zone (Ile-Ife) at 0.05 probability level ($p < 0.05$), this period is the rainy season which is called wet period. High occurrence of lobar pneumonia and sinusitis is associated with maximum air temperature ranges between 30.4^0C and 32.2^0C and average wind speed of about 1.0 ms^{-1} (Figure 6) in the months of January to March at 0.05 probability level ($p < 0.05$); this period is known as dry season. High occurrence of lobar pneumonia ($p < 0.01$) and tonsillitis ($p < 0.05$) is associated with the relative humidity ranges from 67% to 77% in the months of January to March; these diseases reach their peak in the month of March (Figure 5).

In the derived savanna zone (Ilorin) (Fig. 7), high occurrence of bronchial asthma, bronchopneumonia and cardiac asthma associated with maximum air temperature ranges between 27.0^0C and 30.0^0C during rainy season in between the months of June to October ($p < 0.05$), while high occurrence of lobar pneumonia is associated with temperature ranges between 34.0^0C and 35.0^0C during dry season in the months January to March ($p < 0.05$).

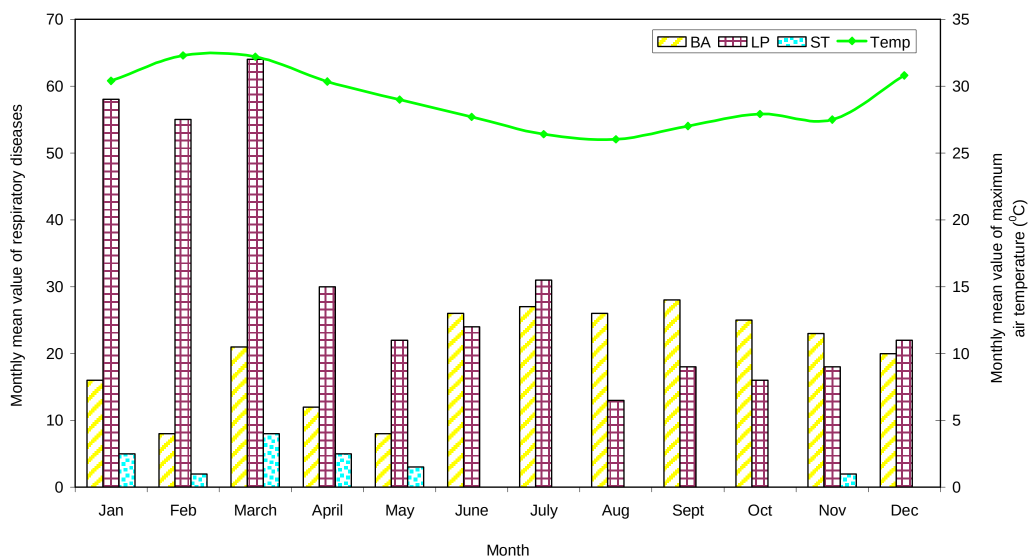

Fig. 4: Monthly pattern of bronchial asthma, lobar pneumonia, sinusitis along with trend of maximum air temperature in humid forest zone (Ile-Ife), Nigeria

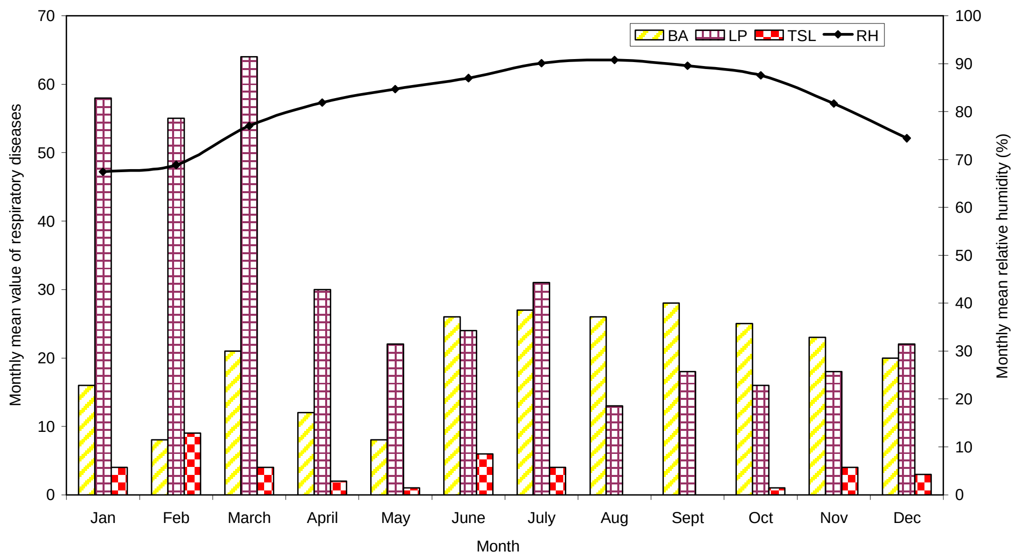

Fig. 5: Monthly pattern of bronchial asthma, lobar pneumonia, tonsillitis along with trend of relative humidity in humid forest zone (Ile-Ife), Nigeria

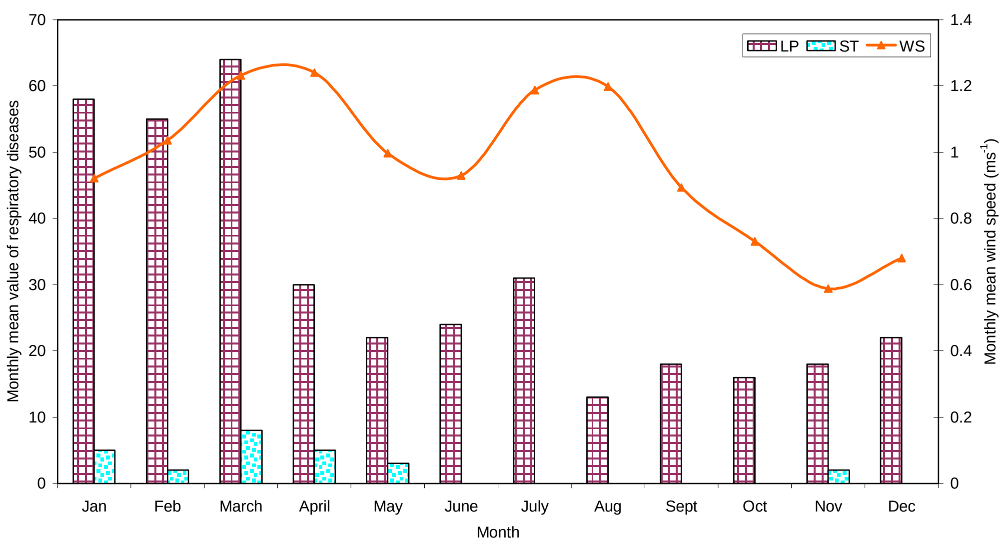

Fig. 6: Monthly pattern of lobar pnuemonia and sinusitis along with trend of wind speed in humid forest zone (Ile-Ife), Nigeria

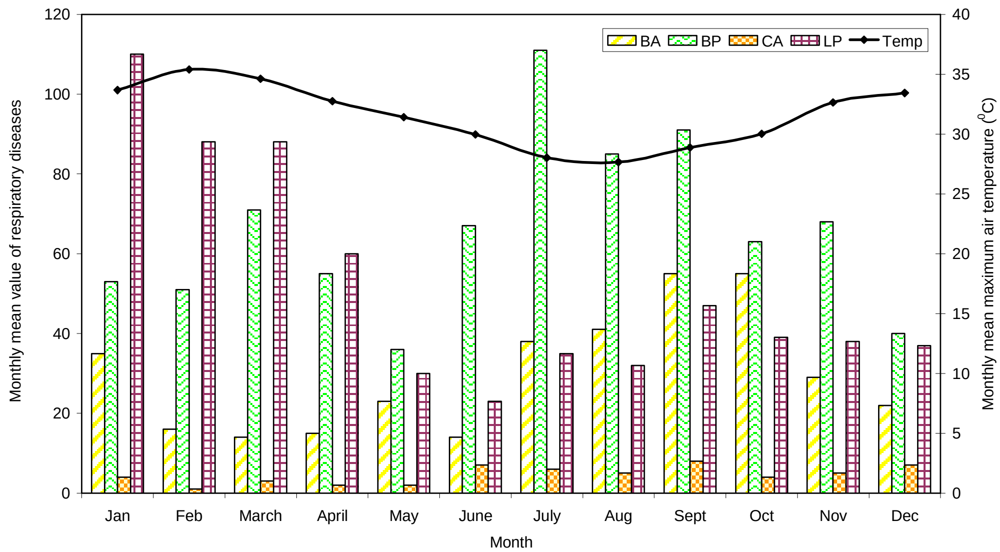

Fig. 7: Monthly pattern of bronchial asthma, bronchopnuemonia, cardiac asthma and lobar pneumonia along with trend of maximum air temperature in derived savanna (Ilorin), Nigeria

5. Discussion

The study revealed that occurrence of specific respiratory diseases considered within the study period is higher in derived savanna (Ilorin) than humid forest (Ile-Ife) which confirmed the results observed by Adefolalu [31], that the higher number of recorded respiratory diseases which require hospitalization in the Southern (forest) part was an order of magnitude less than the cases in the North (savanna) where an average of 250 – 400 cases were treated annually. On the other hand, the results showed that there is high rate of occurrence of selected respiratory in both eco-climatic zones compared to the findings of Adefolalu [31]; this could be a result of high rate of pollution and climate change.

The finding of this study showed that males accounted for a higher percentage of respiratory diseases within the study period. The result confirmed the report of Koren and other notable researchers [32-36] that environmental and occupational factors contribute to higher percentage of respiratory diseases among males in the United States. This is due to higher exposure of males than females to pollens, dusts, indoor and ambient air pollutants among others (depend on the nature of the occupation of individual), which have been identified to reduce the functioning of human lungs [32, 33]. In this part of the world, one of the major occupations is farming, and is predominantly done by men. Meanwhile, researchers have shown that chemicals used as herbicides and pesticides on the farm can cause or trigger respiratory disorder [31, 37-39].

The highest number of respiratory diseases occurred in the age group less than 10 years. This may not be unconnected with the low immunity of children to pathogens causing respiratory diseases. This is similar to the results observed in United States by Mannino et al. [40] that the rate of occurrence of respiratory diseases is increasing more rapidly in preschool – aged children than in any other group. The fact that children are more susceptible to respiratory diseases is well known and is due to exposure of children to smoke, dusts, pollens and some other weather variables that trigger the occurrence of respiratory diseases which immune system of children cannot withstand [24, 41].

High occurrence of bronchial asthma in the two eco-climatic zones and cardiac asthma in derived savanna during rainy season, confirmed the results observed by Omonijo and oguntoke [11] that bronchial asthma increases in the wet season in the tropics. This could be explained by multiple physiologic functions that are modified by blood pressure, sympathetic nervous output, and platelet aggregation [42, 43] during this season.

The high occurrence of lobar pneumonia, sinusitis and tonsillitis in the months of January to March, which falls within harmattan period (November – March) in Nigeria, has been established by many researchers [31, 44-47]. The incidence of harmattan dust haze in Nigeria appears to be reaching alarming proportion which calls for concern, with respect to its possible human-biometeorological effects. The harmattan season has become more intense in the last decade, particularly in the humid forest zone which was hardly affected by thick dust before. The persistence of dust in areas where the influence of harmattan dust haze was a rarity before is a great concern to human health. The significance of such characteristics and trends is in relation to dust pollution and disease spread– especially air-borne diseases which have been confirmed in this study since suspended dust is a major carrier of vectors causing those diseases. The ambient air is usually very dry when the harmattan is prevalent. Such dryness is now being experienced in both humid forest zone and derived savanna zone and even over the entire country.

Furthermore, the positive correlation between air temperature and lobar pneumonia for both humid forest and derived savanna zones confirmed the report of Bull and Morton [48]. According to them, high air temperature causes profound physiologic changes such as an increase blood viscosity and cardiac output leading to dehydration, and even endothelial cell damage [49]. The air temperature at which the lowest lobar pneumonia occurred in this study was around 27^0C. In other areas of the globe, the most favourable air temperature varies, from 26^0C – 29^0C in Taiwan, 22^0C in Sao Paulo, Brazil and 16^0C in the Netherlands [50-52]. Such variation may be explained by differences in housing conditions and by a process of acclimatization to the local climate. Thus, it is important to emphasize the value of thermal comfort, as well as outdoor weather protection for disease prevention, as demonstrated by researchers [53, 54].

The correlation between bronchial asthma and maximum air temperature combined with relative humidity in humid forest zone (Ile-Ife) is consistent with the findings of Tromp [55]. Moreover, there was correlation between bronchial asthma, bronchopneumonia and maximum air temperature in derived savanna zone (Ilorin). This is as a result of drops in temperature during wet season which could lead to increase in sympathetic activity (cardiovascular effects), elevation in plasma noradrenaline [56, 57], activation of the renin – angiotensin system [58, 59]; and alterations in blood and hemostasia, such as the increase in plasmasm in addition to hypercoagulability [42, 60]. The increase in the incidence of respiratory infections during wet season and the consequent activation of the acute inflammatory phase has been related to an elevation in fibrinogen and in the activity of factor VII with a possible increase in thrombogenesis [61, 62].

6. Conclusion

Based on the findings of this study, it is obvious that some weather parameters have influence on respiratory diseases. The number of patients affected with one respiratory diseases or the other is on the increase as compared to 1980s in the two eco-climatic zones (humid forest and derived savanna). It is more in the derived savanna zone. This high increase in the occurrence of respiratory diseases is very common during late dry season and more prevalent during harmattan period at both zones.

The reason for the intense harmattan dust haze over the entire country that led to high occurrence of respiratory diseases cannot be unconnected from the impact of climate change. This is because the declining influence of the monsoon in West Africa appears to have become critical. As a result of this decline, not only rainfall amount is affected both its temporal and spatial spreads in the Sahel were also curtailed. The effect of diminishing vegetation is the exposure of larger expanses of semi-arid soil to agents of weathering and wind erosion which will break down the top soils thus preparing them as dust ready for transport during the dry harmattan season. In view of this, there is need to protect our environment in order not be affected adversely by the impact of climate change and also to ensure sustainable environment for the future generation more so that children are the most vulnerable to the impacts of climate change.

The fact that maximum air temperature, air relative humidity and wind speed explained the pattern of respiratory diseases showed that thermal environment have significant influence on the occurrence of respiratory diseases in the study areas and perhaps, the whole country. Moreover, the seasonal variation in the occurrence of respiratory diseases considered in this study confirmed the role of seasons and weather variation in the occurrence of respiratory diseases.

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