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Full Length Research Paper

Malaria and pneumonia occurrence in Lagos, Nigeria: Role of temperature and rainfall

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The role of climatic parameters in the prevalence and severity of some common diseases is being speculated in the face of changing climate of the world. We investigate this supposition by expounding the relationship between malaria, pneumonia, rainfall and air temperature over Lagos, Nigeria. This study uses temperature and rainfall data of 60 years and 14 years record of reported cases of malaria and pneumonia infection. Significant climatic change was detected in both rainfall and air temperature when standard method of change detection was applied. While rainfall showed a decreasing trend resulting into drier conditions, temperature tends to increase resulting into warmer environment. Temperature spells were found to increase in frequency during the last two decades, and there are tendencies for further increment given the current rate of increasing temperature. Air temperature and malaria correlation coefficient was high and positive in the months of February and December ranging between 40 and 95% but high and negative only in November. Coefficient of correlation between rainfall and pneumonia was high in the range of 50 and 90% and positive in February, May, July and August. The months of March, April, June, September, October and December also showed positive correlation but the coefficients are so weak and insufficient (<20%) to justify reasonable relationship between the variables in these months. We conclude that climatic parameters, rainfall and air temperature, have profound influence on both malaria and pneumonia occurrence and are responsible directly for intractable increase of the diseases.

Key words: Malaria occurrence, change points, climate- disease, pneumonia.

INTRODUCTION

The relationship between human health and weather has been established through direct results of research findings. Such findings have reported increases in certain diseases as a consequence of unusual (otherwise known as extreme and spell events) increases in weather parameters (for example temperature, rainfall, vapour pressure, relative humidity and wind). Ebi et al. (2004) found increases (between 6 and 13%) in hospitalisation for congestive heart failure and stroke among the aged (70+ years) as a result of changes in temperature. In the face of any change in climate, how occurrences and hospitalisation for diseases will change remains highly speculative (Reiter, 2001; IPCC, 2001). The facts that the infrared radiation is trapped by greenhouse gases and particles in planetary atmosphere, and that the atmospheric carbon dioxide (CO_2) level has increased by some 25% since 1850 because of fossil fuel combustion and land use are not controversial (Schneider, 1990). Closely connected to these facts is that global temperature has experienced a rise synchronous with an increasing water vapour attributable to human activities (Willet et al., 2007). Thus the global climate, as measured by increasing positive anomalies of temperature and precipitation, has witnessed certain variability and changes, but how these changes have impacted the local communities remain largely unknown especially in the areas related to health. Any changes in climate parameter especially temperature is anticipated to cause change in outbreak of certain common diseases such as *Plasmodium falciparum* malaria and pneumonia. As reported by Jonathan et al. (2005), many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heat waves, to altered transmission of infectious diseases and malnutrition from crop failures. Persinger (1980)

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found those diseases occurrences are linked to rainy season, considered to be growing season when malnutrition is common. It is speculated that the change in occurrence of the diseases may be due to development of hospitable climate condition, as a result of long term climate variability, suitable enough for longer breeding period of disease – causing insects (mosquitoes in case of malaria). Linking climate variability or change to outbreak or resurgence of certain diseases remains a challenge because fairly long–term data to assess the relationship between climate parameters and diseases is not available, a fact that has also been echoed by Jonathan et al. (2005). It has also been argued that rather than climate change, variations in environmental, social and epidemiological factors are more reasonable explanations for the malaria resurgences in some places in Ethiopia, Madagascar and Tanzania (Hay et al., 2002). In Lagos, however, governmental and non–governmental organisations have intensified efforts at improving the aspect of environmental and epidemiological factors such as enhanced clean environment campaign, provision of insecticide and impregnated nets for vulnerable groups (babies and pregnant women) and other social developmental activities. With these provisions in place, sufficient and accurately administered, it is expected that there should be a suppressed occurrence of malaria or at worst, record of malaria occurrence matching and limited to previous records. In this way, the impact of the provisions can be determined. Given this argument, we aim at investigating the trend of malaria occurrence over the period for which records are available to confirm the above hypothesis.

On the other hand, pneumonia is a condition of illness of the lung. It is an infection which causes the air sacs in the lungs (called the alveoli), and the smaller bronchial tubes to become inflamed and filled with fluid. Special white blood cells then travel to the lungs to fight off the infection. This makes it hard for the lungs to do their job: which is to get oxygen from the air into the bloodstream and then around the whole body (BLF, 2007). The symptoms include cough producing greenish or yellow sputum, or phlegm and a high fever that may be accompanied by shaking chills. Pneumonia is a common illness which occurs in all age groups, and is a leading cause of death among the elderly, children under five years and people who are chronically and terminally ill. Pneumonia claims more children less than 5 years of age in Nigeria (Onche, 2009; Falade and Osinusi, 2009). Reports on how weather affects the occurrence and rate of hospitalization of this disease are, however, still very scarce. Because the disease manifests shaking chills as one of its symptoms, we are of the opinion that weather extremes may have profound effects on patients as to exacerbate its severity, increase hospitalization and cause accelerated death. Weather may have influence in the pneumonia infection not only because of the shaking chill symptom but in creating a favorable atmosphere for the bacteria and virus that cause the infection to thrive. Thus weather may cause an increase in the rate of infection of the disease. Again, this remains to be substantiated with quality data. One of the aims of this study therefore, is to investigate the occurrence and relationship of the disease with weather parameters.

DATA AND METHODOLOGY

Study area and climate

Lagos is a commercial centre in Nigeria with a total of about 9 million inhabitants, a yearly growth rate of 3.2% and second most populous city in the country (Census, 1996). It is also a coastal city bounded by the Atlantic Ocean in the south. Lagos is located partly in the swampy mangrove and partly rain forest regions of West Africa having bi–modal rainfall maxima annually. It receives mean annual rainfall of about 2000 mm (Ojo et al., 2004). Lagos has a tropical savanna climate (Köppen climate classification Aw) that is similar to that of the rest of southern Nigeria. There are two rainy seasons, with the heaviest rains falling from April to July and a weaker rainy season in October and November. There is a brief relatively dry spell in August and September and a longer dry season from December to March. Monthly rainfall between May and July averages over 300 mm (12 inches), while in August and September it is down to 75 mm (3 inches) and in January as low as 35 mm (1.5 inches). The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. The average temperature in January is 27°C (79°F) and for July it is 25°C (77°F). On average the hottest month is March; with a mean temperature of 29°C (84°F); while July is the coolest month (BBC, 2010).

Data

Average daily temperature values over Lagos (Latitude 6.5°N, Longitude 3.3°E) were obtained from National Centre for Environmental Predictions – National Centre for Atmospheric Research (NCEP – NCAR) reanalysis data (Kalnay et al., 1996) between 1948 and 2007. The data are from archive of improved global resolution of 2.5°×2.5°. The integrity of the data has been attested by many researchers (Nicholson and Grist, 2001; Sultan and Janicot, 2003; Camberlin et al., 2001). They have found the data set to be of high quality and suitable for study such as the present. Mean monthly rainfall data of 60 years from 1948 to 2007 was collected from the archive of the Nigerian Meteorological Agency (NIMET), Oshodi Lagos. Annual series were obtained as an average of monthly values. Finally, number of both inpatients and outpatients (medical data) admitted or treated for malaria and pneumonia from 1990 to 2003 were collected from Lagos State University Teaching Hospital, Ikeja. There were missing values and no attempt was made to fill in the values since they are few. We observed that the missing values will not affect our results significantly.

Analyses

In other to determine whether there has been change in the climate parameters used in this study, a method of test of change in temporal data is required. Trend lines applied showed no satisfactory result due to certain deficiencies inherent in the method such as inability to detect non linear change in the data series although trend line is easy to apply to a very large data. We,

Table 1. Statistics of changes in climatic variables.

Parameter	k	α	p	Year	Mb	Mc
Rainfall (mm)	584	0.006	0.994	1970	1941.4	1582.4
Temperature (K)	-690	0.020	0.980	1980	297.57	298.44

K is change parameter; Mb and Mc are means of climatic variables before and after shift respectively while year is the year when significant change curve reached maximum. P is the significant probability and α denoting significance level is calculated as 1 – P.

therefore, sought a non–parametric method of change detection in Mann–Whitney two sample test approach. According to Pettit (1979), in a random sequence of variables $X_1, X_2, X_3....X_T$ a change point is said to be observed if X_t for $t = 1,....\tau$ have common distribution function $F_1(x)$ and X_t for $t = \tau + 1,....T$ have a common distribution function $F_2(x)$ and $F_1(x) \neq F_2(x)$. Suppose

$$D_{ij} = \mathrm{sgn}(X_i - X_j)$$

Where $\mathrm{sgn}(x)$ = 1 if $x > 0$, 0 if $x = 0$ and -1 if $x < 0$

The statistic $U_{t,T}$ is therefore tested for values of t with $1 \leq t < T$. Where

$$U_{t,T} = \sum_{i=1}^{t} \sum_{j=t+1}^{T} D_{ij} \tag{1}$$

A null hypothesis H_0 of no change is tested against alternative H_1 of change using

$$K_T = \max_{1 \leq t < T} \left| U_{t,T} \right| \tag{2}$$

However, $U_{t,T}$ is easily computed by reducing the data to Bernoulli random variables using the method of McGilchrist and Woodyer (1975) and the statistic $U_{t,T}$ is calculated as

$$U_{t,T} = T(S_t - tS_T / T) \tag{3}$$

where $S_t = \sum X_j$ and $S_T = \sum X_j$ summing over 1 to t and 1 to T, respectively. For changes in one direction, the statistics

$$K_T^+ = \max_{1 \leq t < T} U_{t,T}$$

$$K_T^- = -\min_{1 \leq t < T} U_{t,T}$$, Thus;

$$K_T = \max(K_T^+, K_T^-)$$

Approximate significant probability p associated with the value of k^+ of K_T^+ is given by

$$p = \exp\left[-2(k^+)^2 \left\{S_T\left(T^2 - TS_T\right)\right\}^{-1}\right]$$

Furthermore, temperature anomalies have been computed by subtracting from daily temperatures the value of the corresponding day in the mean annual wave, which is estimated as the sum of the first two harmonics to the series of mean daily temperatures. Such harmonics which correspond to an annual and semi annual cycle, explain about 97% of the series variance. Temperature anomaly is classified as 'spell' if its value is located in the third quartile of the corresponding anomaly distribution for months under consideration. The value of the third quartile (75%) is used to obtain a more robust value for extreme spell detection, since only 25% of the station's spell exceeds that value. This criterion, according to Rusticucci and Vargas (2001) is more appropriate than sometimes using standard deviations because the third quartile indicates a probability value, which is not available from the standard deviation since the distributions are highly asymmetrical. Thus, we sub–divide the period considered into six decades starting with 1948/57 and so on for easy comparison. Rainfall, malaria and pneumonia data were treated differently; trends were obtained for both malaria and pneumonia by applying trend lines to the data. Frequency of temperature spells was correlated with both malaria and pneumonia data to determine their relationships. Similarly, correlations between medical data and rainfall were calculated.

RESULTS

Temporal change in rainfall and temperature

Climate change is more properly used to imply a significant change from one climatic condition to another. Scientists however, tend to use the term in the wider sense to also include natural changes in climate, referring to climate change as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period of time, normally decades or longer (IPCC, 2001). We investigate the temporal climatic change in the parameters according to Mann–Whitney test and the result is shown in Table 1. Rainfall displayed a marked shift significant at 0.01 significant level indicating a strong evidence of change. On the other hand, air temperature upward change with α < 0.05 significant level (Table 1) got to the peak in 1980. This indicates that there have been significant air temperature rise beginning from 80's over the study area, and the increase has continued in consistence with

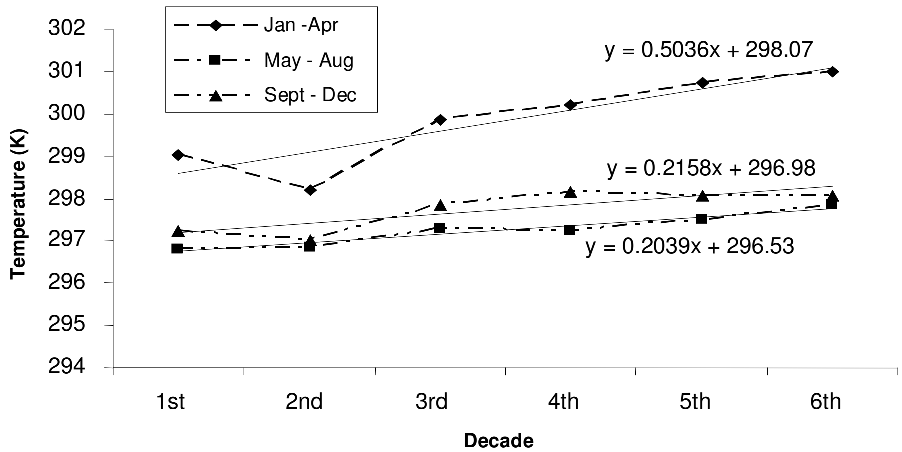

Figure 1. Mean decadal temperature for beginning of rainy season, rainy season and ending of rainy season.

globally predicted average rise in temperature.

Decadal mean temperature

Basically in Nigeria, and indeed in West Africa, two prominent seasons are known, and they are the dry season between December of previous year and March/April of following year, and wet season between April and October/November. However, the span of the seasons shrinks as we progress from the rainforest south through savannah to sahelian zones of the north. For the purpose of this study, a year has been demarcated into beginning of rainy season (January – April), rainy season (May – August) and ending of rainy season (September – December).

Mean decadal air temperature over Lagos shown in Figure 1 reveals that temperature dropped in second decade during the beginning of rainy season but picked in the third decade. The increasing trend continued up to the sixth decade and there is yet no sign of abatement. Meanwhile, both the rainy and ending of rainy seasons have experienced increasing mean temperature, the trend has not been so severe as in during the beginning of rainy season surmising from the steeper slope of the latter's trend line. An increasing trend of about 0.5K per decade was detected for the months in the beginning of rainy season compared to about 0.2K for months in both rainy and end of rainy seasons. Comparison between the first and sixth decades only shows that there have been about 0.65, 0.35 and 0.27% increase over the first decade in the mean decadal temperature for the beginning, rainy and end of rainy seasons, respectively.

Decadal temperature spell

The beginning of rainy season is characterized by moisture build up (Omotosho, 2007) when deep convective systems develop. The development of the systems signifies abundance of moisture as specific humidity anomaly becomes positive. The moisture build up is usually very deeper during the beginning of the rainy season compared to other seasons (Figures 3(a) – (f) in Omotosho, 2007). According to Clausius Clapeyron equation (Willett, 2007), we expect a corresponding increase in temperature due to moisture increase. Thus, months of the beginning of rainy season especially March and April are warmer than the rest of the year. Similarly, the months in rainy season are usually cool/cold because of the cool/cold winds resulting from precipitation. And finally, months of ending of rainy season are usually cool/cold initially due to cool/cold wind from ceasing rainy season and later due to incursion of cold hamattan wind.

Presented in Figures 2(a) – (c) is number of spells days in each category of seasons. Cold spells in the months of January – April were common only in the first and second decades and disappeared completely in the rest of the decades. Second decade, however, had the highest number of cold spell days of about 120 days thereby reducing number of normal adaptable temperature days to record low.

Normal adaptable temperatures reduced considerably henceforth from third decade to sixth decade. In contrast to reducing number of days of normal adaptable temperature, warm spells increased drastically from third decade to highest value of about 60 days during the sixth decade. This is in response to increasing annual temperature over the location. Abnormally high temperatures as manifested by the increasing warm spells have the tendency to exacerbate susceptibility to diseases (Trompson, 1963). Warm spells during the beginning of rainy season characterized by high humidity will increase human discomfort occurring in form of profuse perspiretion, stress and fatigue. This is commonly experienced few weeks before the proper onset of the rain. More

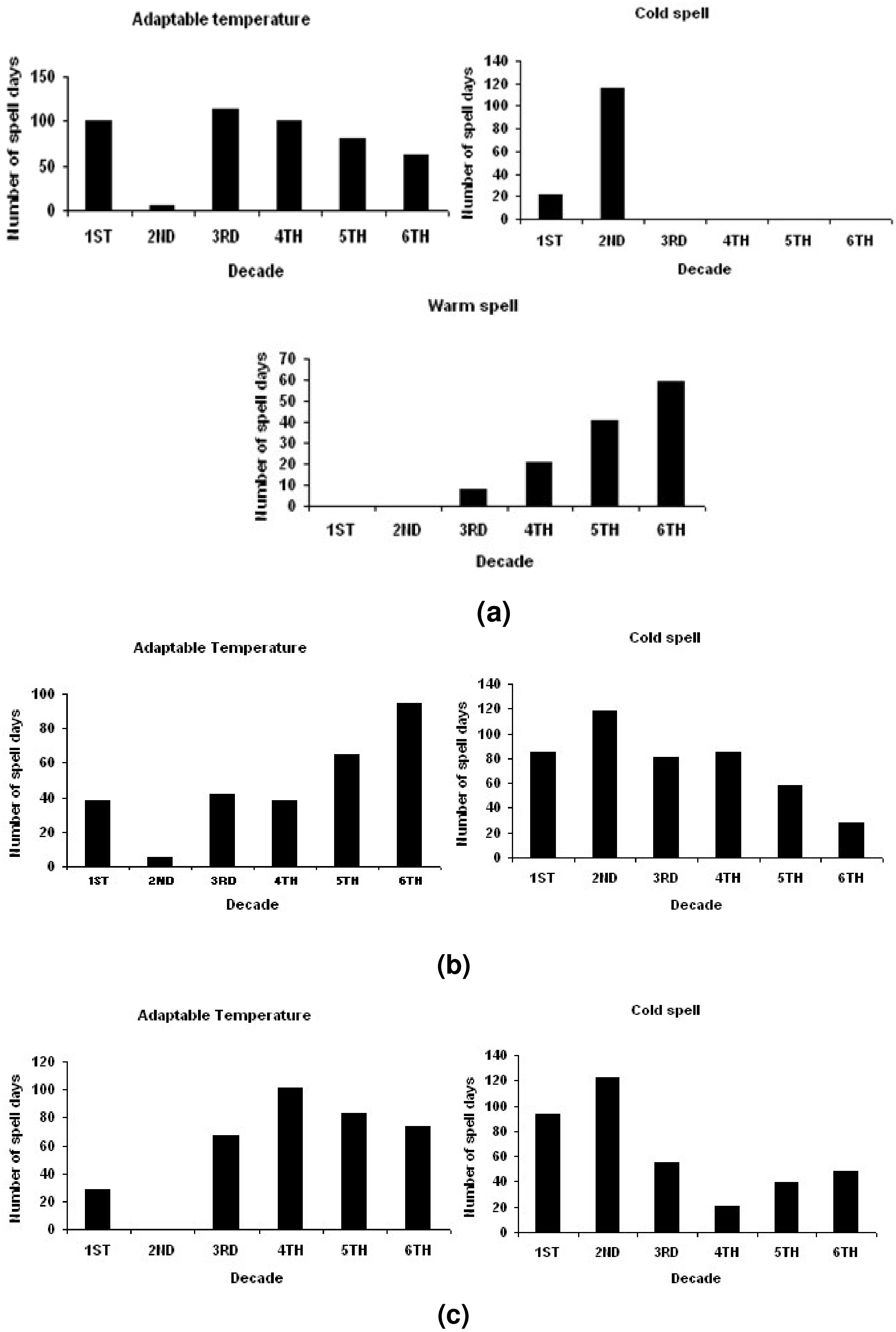

Figure 2. Decadal temperature spells indicating the frequency of cold, warm spells and adaptable temperatures in (a) January – April (b) May – August (c) September – December.

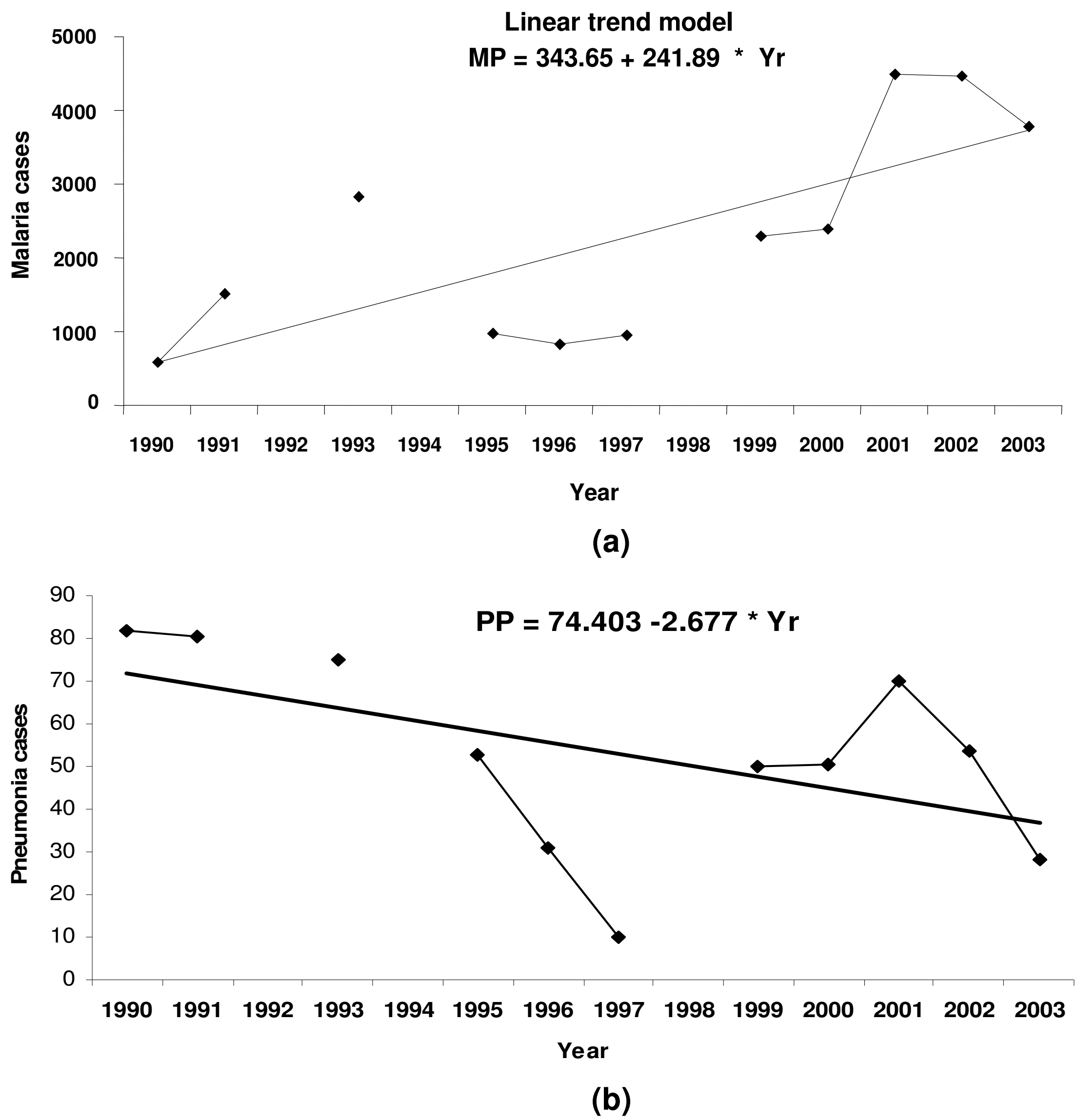

Figure 3. Time series of diseases occurrence: (a) Cases of malaria (MP), (b) cases of pneumonia (PP); the tick line is the trend line which gives the linear model equation.

discomfort is therefore inevitable given the current trend of increasing warm spells during these months.

May – August has high frequency of cold spells, this is expected as this corresponds to period of rainy season.

Trends in reported cases of malaria and pneumonia occurrence

Analysis of reported cases of malaria indicated in Figures 3 (a) and (b) shows that trend in malaria occurrence has risen considerably between 1990 and 2003 at a rate of about 242 patients per year. At this rate, malaria cases reported in 1990 stood at below 1000 cases but grew to over 4000 cases in year 2001. This trend is best described by the linear trend line fitted on the data which shows a positive steeply slope appearing to be on the increase. The increase in malaria occurrence is prevalent among the pregnant women, especially among young maternal age (<20 years) as noted by Agomo et al. (2009) and Mokuolu et al. (2009). While non-climatic factors such as socio-economic influences, immunity patterns and drug resistance effects may be implicated, the increasing trend is apparently related to extreme weather conditions. Although epidemiological data available at present do not allow robust assessment of increasing malaria occurrence with environmental conditions, however, it can be argued that the efforts put in place both by local authorities and international donor agencies at curtailing the malaria attack should have been seen to have impact if climatic information has been considered alongside the administration of the aids. Jonathan et al. (2005) proposed this line of reasoning but concluded that further studies must be conducted and may include the determination of increases of diseases across sex and age group for which we have no data in the present study.

Contrary to malaria occurrences, reported pneumonia cases has decreased significantly from over 80 cases in 1990 to less than 10 cases in 1997 at a rate of approximately -2.7 patients per year. The cases of pneumonia infection rose in 1999 but began to decrease again since 2001. Trend of reported pneumonia cases revealed that malaria occurrences are more severe than pneumonia.

Relationship between climatic parameters and malaria

We describe the relationship between malaria and rainfall in one part and malaria and temperature in the other part using the coefficients of correlation. Coefficients obtained by correlating monthly series of rainfall in a year with similar series of reported malaria cases show no strong relationship. The same observation was made from correlation of the air temperature and malaria cases. The correlation analysis was then carried out using data for each month of the year but taking the total number of year of study altogether. In this way, all January rainfall data between 1990 and 2003 were combined to form a series; the same was done for February and so on to December. Further, air temperature and malaria data were treated in the same manner. The correlation coefficients were plotted against months as shown in Figures 4(a) and (b), correlation coefficient, in case of rainfall versus malaria only was high and positive in the months of January, September, November, and December fluctuating between 40 and 60%. High but negative correlation coefficient was however observed in the months of April, June and October, also in the same range as the months of positive correlation. Thus, if 'decorrelation' is to be defined as $r < 1/e$, then the months of February, May, July, August show very weak relationship between the variables. Air temperature and malaria correlation coefficient was high and positive in the months of February and December ranging between 40 and 95% but high and negative only in November, while the rest of the months showed very weak correlation between the variables.

Relationship between climatic parameters and pneumonia

Depicted in Figures 5(a) and (b) are correlation curves similar to Figure 4, (a) is for rainfall and pneumonia and (b) is for air temperature and pneumonia. The correlation presented here was obtained after the variables had been re–ordered as explained previously following the same reasons. Coefficient of correlation between rainfall and pneumonia was high in the range of 50 and 90% and positive in February, May, July and August. The months of March, April, June, September, October and December also showed positive correlation but the coefficients are so weak and insufficient (<20%) to justify reasonable relationship between the variables in these months. However, January and November showed negative but weak coefficient of correlation. In general, rainfall tends to increase cases of pneumonia infection especially in those months of high positive correlation coefficients. Air temperature plays more important role compared to rainfall in reported cases of pneumonia infection. This is obvious from the high and positive correlation coefficients (between 40 and 60%) prevalence during the cooler months of May, June and July. These months correspond to period of frequent and high intensity rainfall.

On the other hand relationship between air temperature and pneumonia was weak in the months of August through December and January. This period is usually characterized by warmer temperatures, although the temperatures are sometimes reduced by advection of cold air (hamattan) to the study area. Comparing the coefficient of correlation in these warmer months with the value obtained in April, noted as the warmest period of the year due to convective activities associated with formation of tall clouds and onset of rainy season, we observe that the coefficient was higher (>50%) but negative suggesting that April being the warmest month has the least case of pneumonia infection, this brought to the fore the impact of cold environment on the severity of the disease. We note that the period of frequent rain has prevalence pneumonia infection and yet the relationship between rainfall and pneumonia appears to be weak, it is suggested that the reduction in temperature must therefore be due to cloudiness. Tall and deep clouds are common during the rainy season and their presence does not always guarantee that rain will fall on a particular day, but they act effectively as shield blocking off the sun rays and thereby reducing the overall diurnal air temperature.

DISCUSSION

Application of Mann-Whitney method of change detection to the rainfall series over Lagos revealed that the peak of change occurred in 1970 consistent with and comparable to the result of Anyadike (1993) and Tarhule and Woo (1998). Although their studies are based on the analyses of rainfall over northern Nigeria, rainfall producing mechanisms over Lagos (southern Nigeria) and over the reported study areas are essentially the same. Both are basically controlled by the latitudinal migration of inter tropical discontinuity (ITD). The significant change of rainfall trend from wet to dry as indicated by the test statistics is attributable to impact of climate change. The

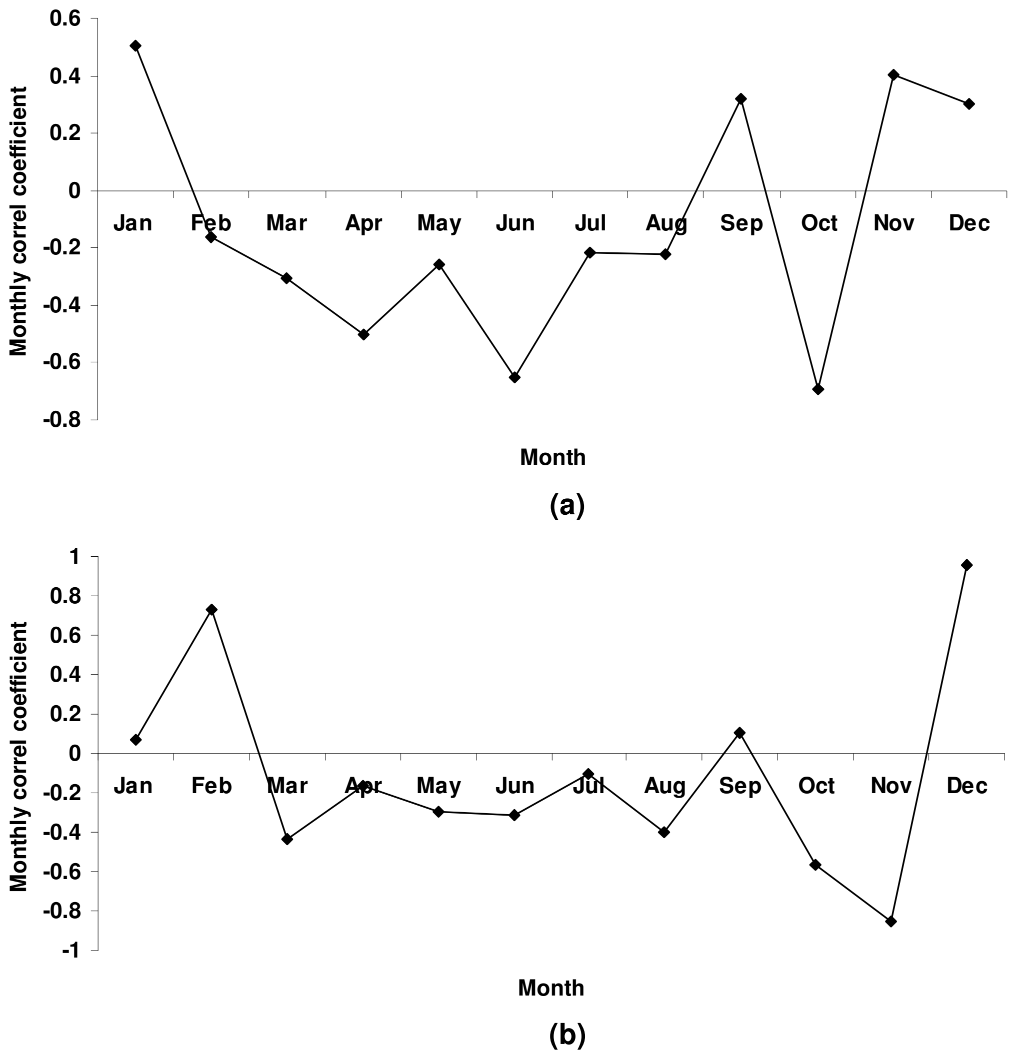

Figure 4. Monthly correlation between (a) rainfall and malaria and (b) rainfall and pneumonia.

protracted dryness and the severe impact on the region as manifested in the extension of arid areas of the sahel has been severally reported (Nicholson et al., 1998; Nicholson and Grist, 2001). The impact of rainfall deficiencies on water resource, agricultural practices and river flow, generally in West Africa, has been discussed (Ojo et al., 2004). Similar change was observed in the temperature series when the same method was applied. Again, the significant change in temperature is attributable to climate change as caused by both natural and anthropogenic agents. Rapid urbanization, in terms of house and road constructions and landscaping are a major anthropogenic activity which has been very high in Lagos in the last three decades, this coupled with heat generated from increasing traffic density are local factors contributing to increasing temperature rise. The worldwide temperature increase may have exacerbated the rise in temperature over Lagos, thus the significant change observed. Similar observation has been made for extreme temperatures over west and southern Africa as the study by New et al. (2006) has indicated. The statistically significant change observed in both temperature and rainfall clearly indicates a change in the climate over Lagos as reported for many places around the world. Increase in daily average temperature has resulted in spells that were not experienced prior to the change. As found out in this study, the cold spell days have witnessed reduction attributable to rising temperature. The consequence of this is that number of days of normal adaptable temperatures has increased correspondingly. There are no warm spells detected yet during the rainy season. September – December is predominantly hamattan period when the cold often dusty winds blow from north east of the country to the station. Decreasing cold spells days is again apparent during this period in favour of increasing frequency of normal adaptable temperatures without warm spells days. Although, warm spells are visibly absent from months of rainy and ending of rainy

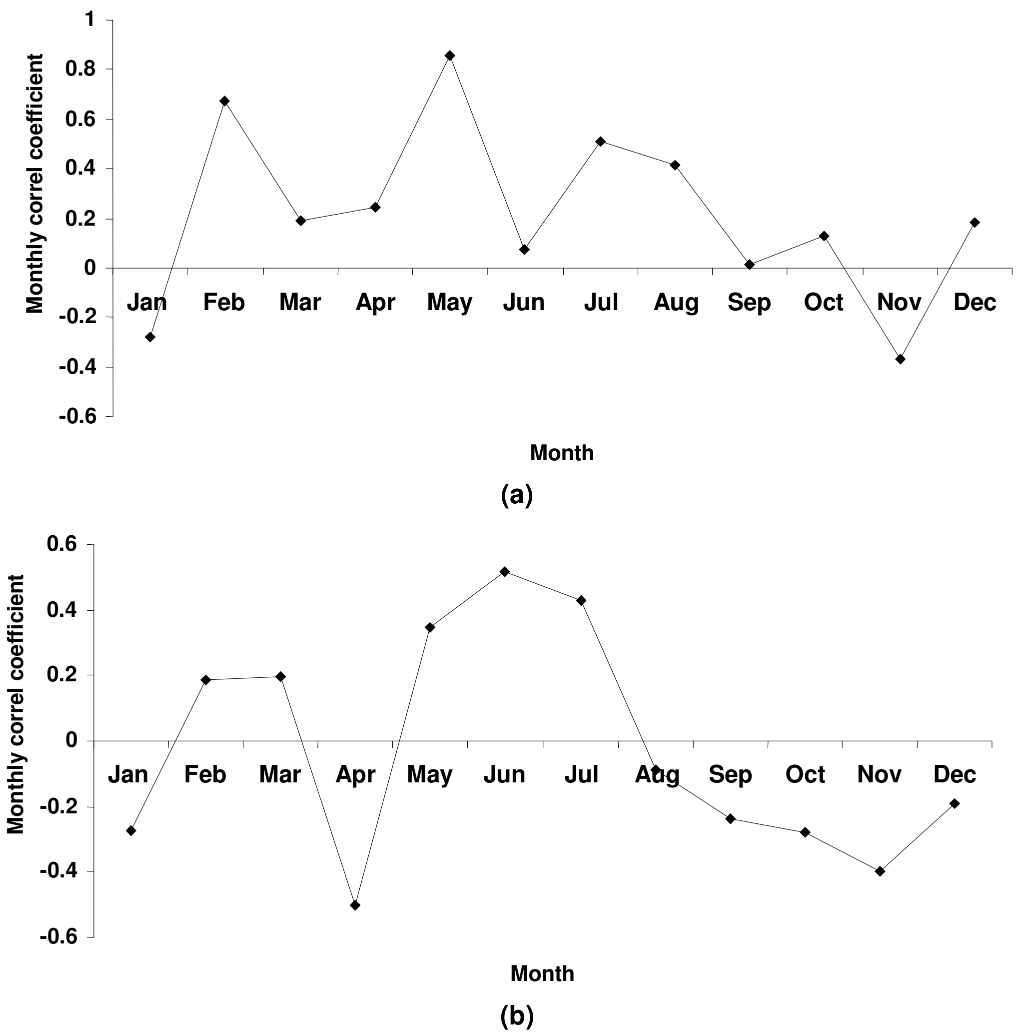

Figure 5. Monthly correlation between (a) air temperature and malaria and (b) air temperature and pneumonia.

seasons, projecting at the current rate of warming, it appears that emergence of warm spells may be unavoidable in the future.

Correlating climatic parameters (rainfall and temperature) with some diseases (malaria and pneumonia) revealed the influences of climatic parameters on the diseases. First, it can be observed that correlation series alternate between periods in case of rainfall versus malaria, for example malaria attack was common in November, December and January, these three months correspond to the period of dry season when streams are stagnant, ponds are stable and waterways are able to retain pockets of stagnant water. These conditions allow breeding of mosquito and burgeoning population, thus the high correlation coefficients indicate the dependence of increased malaria attack on insufficient rain or total rainless climatic conditions. On the other hand, negative correlation or diminished malaria attack occurs during the wet season when flowing of rivers and continual waterways and ponds surface disturbance would not give enough time for breeding of mosquito but wash away mosquito eggs at each fall of rain. Secondly, we note the appearance of a situation in which a dry or wet month is immediately succeeded by high or low malaria occurrence respectively. The most vivid is the case of little dry season which occurs in July/August; this boosted mosquito reproduction and the effect is seen in September high malaria attack. Air temperature and malaria out break relationship is less definite, however malaria appear to subside during periods of low temperature especially during the wet period, which perhaps suggests that relatively low temperatures are less favourable to mosquito reproduction.

Despite the revealed influences of the climatic parameters on the diseases under study, there are certain limitations to utilizing the results obtained. One of such limitation is the lack of long term data for development and testing of climate - disease models.

Social and etymological factors are major limitations to validation of the results (Jonathan et al., 2005). Most people do not visit hospital perhaps due to ignorance or lack of access to health facility, thus the data collected on the diseases are not strictly representative of the general population. However, this kind of study demonstrates that climate elements play crucial role in the spread and severity of the diseases.

Conclusion

Diseases such as malaria and pneumonia are leading causes of death in Nigeria. Malaria pandemic alone has caught the attention of both the local authorities and international agencies. Several measures have been adopted to reduce the rate of morbidity due to malaria. But we found out from this study that the rate of reported cases of malaria is yet to subside. Since we are aware that the agencies in charge of controlling the disease have done so much to improve the environmental factors, we look further away into the role of climatic parameters such as rainfall and temperature on the occurrence and prevalence of both malaria and pneumonia.

First, this study has shown that these climatic parameters had changed significantly over the past two/three decades. The increase, especially in temperature was noted to have continued at a globally predicted rate. Rainfall on the other hand declined resulting into drier conditions. Secondly, in accordance with the significant changes observed in temperature, spells of temperature were noted to be more frequent in the last three decades with the highest in the most recent decade. It is expected that frequency of spells may continue to increase if the increasing trend of air temperature persists. Finally, this study has established the link between climatic parameters and prevalence of some common diseases as earlier suggested by Jonathan et al. (2005).

The same fact was established by Leovinsohn (1994) from modelled rainfall and malaria relationship in which it was found that rainfall acts on malaria through lags of 2 – 3 months in Rubona highlands of Rwanda. The study showed that non–climatic factors implicated elsewhere were less important in the catchments area considered. The relationship between rainfall and malaria indicated that reported cases of malaria occurrences are more prevalent during moderately dry periods. The dry periods allow for breeding time and reduction in cases of malaria is due to rain wash out. Temperature appears to be more important in cases of reported pneumonia infection as indicated by the low/weak and negative correlation coefficient during warmer periods. We have attributed the increased cases of reported pneumonia infection during the raining season to the sun ray shielding effects of cloud and overall reduction in diurnal temperature and not to the rainfall itself. Pneumonia and rainfall did not show any definite relationship as indicated by irregular and weak correlation between the two variables. The study has shown that climatic factors are important and should be considered along with other factors in mitigating the spread of common diseases such as malaria and pneumonia.

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