

**EFFECTS OF SOME WEATHER ELEMENTS ON THE OCCURRENCE OF MALARIA,
TYPHOID AND TUBERCULOSIS CASES IN ONITSHA NORTH LGA, ANAMBRA
STATE, NIGERIA.**

BY

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MAY, 2016

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**ADISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
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GEOGRAPHY**

**DEPARTMENT OF GEOGRAPHY
FACULTY OF SCIENCE
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA**

MAY, 2016

DECLARATION

I declare that this dissertation titled **“Effects of Some Weather Elements on the Occurrence of Malaria, Typhoid and Tuberculosis Cases in Onitsha North LGA, Anambra State, Nigeria”** was carried out by me in the Department of Geography under the supervision of Prof E.O Igusi and Dr. B.A. Sawa. This work has not been previously presented or submitted for any other form of certification. All authorities have been duly acknowledged.

.....

Elizabeth Nkolika Anumonye

.....

Date

CERTIFICATION

This dissertation titled “**Effects of Some Weather Elements on the Occurrence of Malaria, Typhoid and Tuberculosis Cases in Onitsha North LGA, Anambra State, Nigeria**” by Elizabeth Nkolika Anumonye meets the regulations governing the award of the degree of Master of Science in Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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Chairman, Supervisory Committee

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DEDICATION

This work is dedicated to my Heavenly Father, the author and finisher of my faith and to my entire family whose guidance and prayers have been my support.

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First of all, I give glory to God who has been so wonderful and kind to me in all that I have been doing. I would like to express my appreciation to my supervisors Prof E.O. Iguisi and Dr B.A. Sawa for their intellectual contributions and constructive criticisms, valuable suggestions and contributions of relevant materials, assistance and guidance.

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ABSTRACT

Human health is affected by weather elements such as temperature, rainfall, relative humidity, wind direction and others. The aim of this study was to examine the effect of rainfall, temperature and relative humidity on the occurrence of malaria, typhoid and tuberculosis in Onitsha North LGA, Anambra State, this was achieved through the following objectives; determine the pattern of occurrence of rainfall, temperature and relative humidity, determine the pattern of distribution of cases of malaria, typhoid and tuberculosis, determine the pattern of distribution of cases of malaria, typhoid and tuberculosis and to determine the seasonality of malaria, typhoid and tuberculosis (2004-2013). Records of rainfall, temperature and relative humidity was obtained from Anambra State NIMET office, Awka and the records of malaria, typhoid and tuberculosis cases from the selected hospitals (2004-2013) were also used to carry out this study. Time series analysis was used to analyze the trends of each of the data collected. Pearson Product Moment Correlation analysis was used to analyze the relationship between the occurrence of the three diseases and the climatic parameters. The seasonal occurrence of the diseases was analyzed by dividing the year into cold dry season, hot dry season and rainy season. The analysis showed that rainfall, relative humidity and malaria exhibited decreasing trends while temperature, typhoid and tuberculosis exhibited increasing trends within the period 2004-2013. The correlation analysis indicated that malaria, typhoid and tuberculosis are influenced differently by the various weather elements. Rainfall showed a significant relationship with malaria with an r value of 0.646 and an insignificant relationship with typhoid and tuberculosis having r values of 0.519 and -0.341 respectively, while temperature showed no significant relationship with any of three diseases with malaria having an r value of -0.194, typhoid; -0.253 and tuberculosis; -0.102. Relative humidity showed a significant relationship with malaria and typhoid with r values of 0.852 and 0.807 respectively and an insignificant relationship with tuberculosis with r value of -0.427. The seasonal analysis showed that malaria and typhoid had their highest number of occurrences in the rainy season with 84.87 and 2.46 cases and their lowest in the cold dry season with 76.62 and 1.75 cases relatively, while tuberculosis had its highest number of occurrence in the cold dry season with 16.97 cases and the lowest reported case reported in the rainy season with 11.31 cases. The hypothesis was tested and accepted in the case of tuberculosis and rejected in the case of malaria and typhoid in the study area. It was recommended that all the three tiers of government should come up with enlightenment programs should be

conducted to educate people on the effect of climate change on the occurrence of diseases; to also provide safe and adequate drinking water for the masses; and provide free mosquito nets for the residents of the area. The people on the other hand should improve on their sanitation in their environment.

TABLE OF CONTENTS

Title Page	i
Declaration	ii
Certification	iii
Dedication	iv
Acknowledgement.....	v
Abstract.....	vi
Table of Contents.....	viii
List of Tables	xiv
List of Appendices	xv
List of Figures	xvii

CHAPTER ONE: INTRODUCTION

1.1	Background to the Study.....	1
1.2	Statement of the Research Problem.....	6
1.3	Aim and Objectives.....	9
1.4	Research Hypothesis.....	10

1.5	Scope of the Study.....	10
1.6	Justification of the Study.....	11

CHAPTER TWO: LITERATURE REVIEW

2.1	Introduction.....	12
2.2	Historical Evidence of the Relationship Between Climatic Conditions and the Occurrence of Diseases.....	13
2.3	Climate Change and Infectious Diseases.....	15
2.4	Sensitivity of Infectious Disease to Climate.....	17
2.4.1	Sensitivity of infectious diseases to temperature.....	17
2.4.2	Sensitivity of infectious diseases to precipitation.....	18
2.4.3	Sensitivity of infectious diseases to humidity.....	20
2.5	Seasonality of infectious diseases.....	20
2.5.1	Seasonality of malaria.....	21
2.5.2	Seasonality of typhoid.....	28
2.5.3	Seasonality of tuberculosis.....	30

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1	The Study Area.....	33
3.1.1	Location and size.....	33
3.1.2	Climate.....	36
3.1.3	Relief and drainage.....	36
3.1.4	Soils and vegetation.....	37
3.1.5	Geology.....	37
3.1.6	Population.....	38
3.1.7	Human activities.....	38
3.1.8	Environmental challenges.....	39
3.2	Methodology.....	40
3.2.1	Types and sources of data.....	40
3.2.2	Sampling technique.....	40
3.2.3	Presentation of data.....	41
3.2.4	Data analysis.....	41

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1	Introduction.....	42
4.2	Trends of the Weather Elements in the Study Area.....	42
4.2.1	Trend in rainfall distribution (2004-2013).....	42
4.2.2	Trend in temperature distribution (2004-2013).....	43
4.2.3	Trend in the distribution of relative humidity (2004-2013).....	44
4.3	Trends in the Occurrence of the Common Diseases in the Study Area.....	46
4.3.1	Trend in the occurrence of malaria (2004-2013).....	46
4.3.2	Trend in the occurrence of typhoid (2004-2013).....	47
4.3.3	Trend in the occurrence of tuberculosis (2004-2013).....	48
4.4	Relationship Between the Various Weather Elements and the Selected Diseases...	50
4.4.1	Relationship between rainfall and the occurrence of malaria.....	51
4.4.2	Relationship between temperature and the occurrence of malaria.....	51
4.4.3	Relationship between relative humidity and the occurrence of malaria.....	51
4.4.4	Relationship between rainfall and the occurrence of typhoid.....	52

4.4.5	Relationship between temperature and the occurrence of typhoid.....	52
4.4.6	Relationship between relative humidity and the occurrence of typhoid.....	52
4.4.7	Relationship between rainfall and the occurrence of tuberculosis.....	53
4.4.8	Relationship between temperature and the occurrence of tuberculosis.....	53
4.4.9	Relationship between relative humidity and the occurrence of tuberculosis.....	54
4.5	Seasonality of the Diseases in Onitsha North Local Government Area.....	55
4.5.1	Seasonality of the three diseases in (2004).....	55
4.5.2	Seasonality of the three diseases (2005).....	56
4.5.3	Seasonality of the three diseases (2006).....	57
4.5.4	Seasonality of the three diseases (2007).....	58
4.5.5	Seasonality of the three diseases (2008).....	59
4.5.6	Seasonality of the three diseases (2009).....	60
4.5.7	Seasonality of the three diseases (2010).....	62
4.5.8	Seasonality of the three diseases (2011).....	63
4.5.9	Seasonality of the three diseases (2012).....	64

4.5.10	Seasonality of the three diseases (2013).....	66
4.5.11	Meanannual seasonality of malaria, typhoid and tuberculosis (2004-2013)...	67
4.6	Discussion.....	68
 CHAPTER FIVE: SUMARRY, CONCLUSION AND RECOMMENDATION		
5.1	Summary.....	72
5.2	Conclusion.....	74
5.3	Recommendations.....	75
References.....		76
Appendix.....		90

LIST OF TABLES

Table		Page
Table 4.1:	Correlation Between the Weather Elements and Malaria, Typhoid and Tuberculosis.....	50

List of appendices

4.1.1	Data on temperature (2004 to 2013).....	90
4.1.2	Data on rainfall (2004 to 2013).....	93
4.1.3	Data on relative humidity (2004 to 2013).....	94
4.2.1a	Data on malaria cases from iyienu missionary hospital (2004 to 2013).....	95
4.2.1b	Data on typhoid cases from iyienu missionary hospital (2004 to 2013).....	96
4.2.1c	Data on tuberculosis cases from iyienu missionary hospital (2004 to 2013).....	97
4.2.2a	Data on malaria cases from st. Charles borromeo hospital (2004 to 2013).....	98
4.2.2b	Data on typhoid cases from st. Charles borromeo hospital (2004 to 2013).....	99
4.2.2c	Data on tuberculosis cases from st. Charles borromeo hospital (2004 to 2013)...	100
4.2.3a	Data on malaria cases from Onitsha general hospital (2004 to 2013).....	101
4.2.3b	Data on typhoid cases from Onitsha general hospital (2004 to 2013).....	102
4.2.3c	Data on tuberculosis cases from Onitsha general hospital (2004 to 2013).....	103
4.2.4a	Data on malaria cases from stPatricks hospital and maternity (2004 to 2013)...	104
4.2.4b	Data on typhoid cases from stPatricks hospital and maternity (2004 to 2013)...	105

4.2.4c	Data on tuberculosis cases from stPatricks hospital and maternity (2004 to 2013)...	106
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LIST OF FIGURES

Figure	Page
Figure 3.1: Location of Onitsha North in Anambra State.....	34
Figure 3.2: Map of Onitsha North Local Government Areas.....	35
Figure 4.1: Trend of Rainfall in Onitsha North Local Government Area (2004-2013)...	42
Figure 4.2: Trend of Temperature in Onitsha North Local Government Area (2004-2013).	44
Figure 4.3: Trend of Relative Humidity in Onitsha North Local Government Area (2004-2013).....	45
Figure 4.4: Trend in the Occurrence of Malaria in Onitsha North Local Government Area (2004-2013).....	46
Figure 4.5: Trend in the occurrence of Typhoid in Onitsha North Local Government Area (2004-2013).....	47
Figure 4.6: Trend in the occurrence of Tuberculosis in Onitsha North Local Government Area (2004-2013).....	49
Figure 4.7: Seasonality of Malaria, Typhoid and Tuberculosis (2004).....	55
Figure 4.8: Seasonality of Malaria, Typhoid and Tuberculosis (2005).....	56
Figure 4.9: Seasonality of Malaria, Typhoid and Tuberculosis (2006).....	57
Figure 4.10: Seasonality of Malaria, Typhoid and Tuberculosis (2007).....	58
Figure 4.11: Seasonality of Malaria, Typhoid and Tuberculosis (2008).....	60
Figure 4.12: Seasonality of Malaria, Typhoid and Tuberculosis (2009).....	61

Figure 4.13: Seasonality of Malaria, Typhoid and Tuberculosis (2010).....	62
Figure 4.14: Seasonality of Malaria, Typhoid and Tuberculosis (2011).....	63
Figure 4.15: Seasonality of Malaria, Typhoid and Tuberculosis (2012).....	65
Figure 4.16: Seasonality of Malaria, Typhoid and Tuberculosis (2013).....	66
Figure 4.17: Seasonality of Malaria, Typhoid and Tuberculosis (2004-2013).....	67

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Human health is affected by natural environmental factors such as temperature, rainfall, relative humidity, wind direction and others. Weather is the state of the atmosphere at a specific time and place while climate is the long-term manifestations of weather and other atmospheric conditions in a given area. Disease is an abnormal condition of the body or mind that causes discomfort or dysfunction (English 1.2.2 dictionary, 2011). Global warming which is defined by Oxford Dictionary of Science (2005) as an increase over time of the average air temperature of the earth.

Climate affects health in a number of ways; this was reported by Tong (2002) who performed an ecological time series analysis to examine the ecological association between climate variability and the transmission of Ross River Virus (RRV) diseases between 1985 and 1996 in Queensland. The result indicated that although many factors can affect the RRV transmission cycles, RRV is generally sensitive to climate variability and that rainfall, temperature and tidal level appeared to be important meteorological determinants in the transmission cycles of RRV diseases at macro level. According to Thorpe, Frieden, Laserson, Wells and Khatri (2004); in the pre-antibiotic era, tuberculosis mortality rate was higher in the late winter and early spring than any other time of the year, it was suggested that environmental and social factors such as temperature, humidity, sunlight as well as crowding and person-to-person contacts are a source of tuberculosis seasonality particularly in the winter time. Continuous research into the influence of meteorological parameters on infectious diseases is a veritable

strategy for proffering sustainable solution to their morbidity; this is because climate affects infectious diseases more than most other disease categories especially in Africa, where the burden of infectious diseases is highest (Wilkinson, 2006). Of the 56 million deaths per annum estimated by WHO as the global burden of diseases, infectious diseases accounted for more than 26percent. Tuberculosis and other respiratory infections are two of the four major contributors to these diseases (WHO 2004a). Going by a recent WHO Global TB Report (2010) approximately 4,700 people die of TB infection daily and a total of 1.7 million deaths in 2009 were due to human infection by the disease.

Researchers like Sawa and Bukhari, (2010); Brunkard, Cifuentes and Rothenberg, (2008); Ayoade (1982) among others have found that there is a close link between local climate and the occurrence or severity of some diseases. Ayoade (1982) stated that weather has the potential to alter the average exposure of condition that is suitable for the vector and disease pathogen. Weather and climate can influence host defenses, vectors, pathogens and habitat, (Epstein, 2002). The temporal and spatial changes in temperature, precipitation and humidity expected to occur under different climatic scenario could affect the biology and ecology of the vectors and intermediate hosts and consequently the risk of disease transmission, WHO (2002). Brunkard, Cifuentes and Rothenberg (2008) stated that climate affects health in a number of ways. These effects may be direct as with heat stress, or indirect as with infectious diseases such as malaria and meningitis (Climate and Health Resources Room, 2008; Griffiths, 1976). The effect may also be either directly on the human body or indirectly through effects on disease-causing organism or their vectors (Checkley, Epstein, Gilman, Figueroa, Cama, Patz and Black, 2000; Chew, Doraisingham, Ling, Kumarasinghe and Lee, 1998; Sung, Murray, Chan, Davies

and French, 1987). Temperature and rainfall are climatic causal factors of diseases and a small change in these parameters is likely to have a significant impact on the spread of diseases (Epstein, Diaz, Elias, Grabhern, Graham and Martens, 1998; Bate, 2004). The effects of high temperatures on human health are modified by the amount of moisture in the air.

Furthermore, the importance of examining the role of weather on human health cannot be over emphasized. Abrupt changes in weather, such as those associated with the passage of a weather front have been implicated in human discomfort with symptoms such as headache. Changes in weather have been demonstrated to be associated with changes in birth rates, sperm counts, outbreaks of pneumonia, influenza and bronchitis (Kalkstein and Valimont, 2008). Certain levels of humidity are ideally suited to the survival and reproduction of pathogens such as bacteria, viruses, parasites, and their vectors (Nathanson and Martin, 1979). Precipitation leads to increased humidity with consequent effects on humans (Greenwood, 1987) and cold weather adds to chilling of human body, thereby making it more susceptible to disease or aggravating chronic diseases. Scott-Evans (2007), for example noted that some people have symptoms that worsen with cold weather while others suffer more in hot weather. Kalkstein and Valimont (2008) also traced the larger increases of mortality to hot weather extremes which brings about several illnesses. According to Kalkstein and Valimont (2008), low humidity leads to excessive dehydration of nasal passages and the upper respiratory tract during winter and increases the chances of microbial and viral infections. 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. 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 (Kalkstein and Valimont, 2003). Winter weather has been linked with increased rates of morbidity and mortality of respiratory diseases including tuberculosis (Nakaji, Parodi, Fontana, Umeda Suzuki and Sakamoto, 2004).

The seasonal variability of tuberculosis is quite clearly demonstrated by the epidemiological data; showing mostly a peak in early spring and summer months, (Fares, 2011). Similarly, Abeku (2007) observed that rainfall is considered to be a major factor influencing malaria cases in Africa. Small, Hay and Goetz (2003) found that rainfall rather than temperature was the primary influencing factor in malaria transmission trends in Africa during most of the twentieth century. At least, most of today's human malaria population *P. falciparum* and *P. vivax* may have had their origin in West Africa and Central Africa respectively ([Joy](#), Feng, Mu, Chotivanich and Kretti, [2003](#)). Nigeria is known for a high prevalence of malaria ([Federal Ministry of Health, 2001](#); [Onwujekwe](#), Chima and Okonkwo, [2000](#)) and it is a leading cause of morbidity and mortality in the country ([Federal Ministry of Health, 2001](#)).

As earlier mentioned, climatic variations and extreme weather events have profound impacts on infectious disease. Air temperature dependencies are seen in correlations between disease rates and weather variations over weeks, months, or years (Omonijo and Oguntoke, 2009; Kuhn, Campbell-Lendrum, Armstrong and Davies, 2003; Omonijo, 2008) and in close geographic associations between key climatic/weather variables and the distributions of important vector-borne diseases (Hales, Wet and Maindonald, 2002; Rogers and Randolph, 2000). Impacts of global weather patterns on the environment and living beings are now more

visible than ever before, as glaciers shrink, ice breaks up on lakes and rivers at faster rates, trees and animal population shift irregularly, and natural and devastating calamities become a common occurrence.

The rate of reproduction, spread and bites by many pests and disease pathogens depends on weather patterns and are usually high in warmer and wetter conditions. Warming also increases the number of pests and microorganisms due to the creation of optimal circumstances for both metabolism and reproduction at the interface of temperate conditions; this is directly correlated to the transmission and spread of diseases (Robert, 2012). Humans have long recognized that climatic conditions influence the appearance and spread of epidemic diseases (NRC, 2001). Hippocrates observation of seasonal illnesses in the fifth century B.C.E. formed the basis for his treatise on epidemics. Hippocratic medicine which attempted to predict the course and outcome of an illness according to its symptoms also considered winds, waters and seasons as diagnostic factors. Ancient notions about the effects of weather and climate on disease remain in the medical and colloquial lexicon, in terms such as “cold” for rhinovirus infections, “malaria” derived from the Latin word for “bad air” and the common complaint of feeling “under the weather”.

Today, evidence that the earth’s climate is changing is leading researchers to revisit the long standing relationship between climate and disease from a global perspective (IPCC, 2007b). Increased atmospheric and surface temperatures are already contributing to the world wide burden of disease and premature deaths, and are anticipated to influence the transmission dynamics and geographic distribution of malaria, dengue fever, tick-borne diseases and diarrhea diseases such as cholera (IPCC, 2007a). Global warming is also accelerating the world wide

hydrological cycle, increasing the intensity, frequency and duration of droughts; heavy precipitation events and flooding (IPCC, 2007a). These weather events may in turn contribute to and increase the risk for a wide range of vector and non-vector-borne diseases in humans and animals (IPCC, 2007b).

1.2 STATEMENT OF THE RESEARCH PROBLEM

A study carried out by Climate and Health Resources Room (CHRR, 2008) on climate and malaria in Africa showed that where malaria is not adequately controlled, its distribution and seasonality are closely related to seasonal characteristics of the weather, and where there were cases of anomalies such as rainfall anomalies, malaria which is seasonally endemic becomes epidemic in warm semi-arid regions of Africa. Akinbobola and Omotosho (2004) looked at the relationship between meteorological variables and the occurrence of malaria, measles, chicken pox, meningitis and pneumonia in Ikeja, Akure and Kaduna and their results showed that there is a relationship between diseases and the seasons. It showed that malaria and pneumonia are associated with the rainy season while measles, chicken pox and meningitis are common during hot periods. Adefolalu (1984); Sawa and Bukhari (2010) investigated how temperature relates with respiratory diseases in northern Nigeria and discovered that the diseases thrive more when the temperature is very low.

Ilemona (1983) studied the occurrence of pneumonia among children below the age of 5 years in Zaria and reported that the occurrence of pneumonia widely depends on the variability of weather, indicating that colder months recorded more cases of the disease. Ogbaji (2006) studied the role of temperature in the distribution of malaria in Zaria. The researchers result

showed that there is a positive relationship between temperature extremes and the prevalence of malaria. December to February recorded less cases of malaria while March to May recorded more cases. Kaplan (2009) researched into the effects of the weather patterns on head ache and it was clear that patients were sensitive to a combination of temperature and humidity changes, demonstrating that there is a relationship between weather and migraine. Malek (1999) showed that high humidity can aggravate arthritis and a warm wind might bring on migraine and emphasized that the effect of temperature on human health is more when compared to humidity and air pressure. Oshaji (2000) studied the effect of weather in the distribution of some common diseases in Zaria and discovered that there is a relationship between temperature extremes and cerebro-spinal meningitis. Bukhari (2009) studied temperature and rainfall variability and the outbreak of cerebro-spinal meningitis and measles in Zaria Local Government Area and observed that there is a strong positive relationship between temperature and outbreak of cerebro-spinal meningitis. Measles showed a negative relationship with rainfall while meningitis had no significant relationship with rainfall. Bako (2012) investigated the influence of weather elements on the occurrence of some common diseases in Kafanchan, Kaduna state using correlation and regression analysis. The researcher observed that malaria showed a significant relationship with both rainfall and relative humidity and also that there is a significant relationship between typhoid fever and relative humidity and rainfall and that the occurrence of typhoid is higher when relative humidity is higher during the rainy season. The researcher concluded that although various diseases are influenced by different weather elements, humidity has a high impact on malaria, pneumonia and diarrhea, temperature on measles and meningitis, rainfall on typhoid and cholera. Ayanlade, Adeboye and Babatimehin (2013) found out that malaria transmission based on climatic parameters occurred between April and October in their

zone B classification of Nigeria of which Anambra State was part of. Using Principal Component Analysis (PCA), Non-hierarchical Clustering and GIS raster techniques, they concluded that seasonality of climate influences the variation in malaria transmission in Anambra State and Nigeria as a whole.

Most of the cited studies were carried out in the northern part of Nigeria and they focused mainly on the effect of some weather elements on the occurrence of malaria, pneumonia, meningitis and migraine. Only few studies e.g. Ayanlade, Adeboye and Babatimehin (2013) focused on the south eastern part of the country (Anambra State as a whole), and they only looked at malaria. To the best of the researcher's knowledge, there is no study that has correlated weather elements of temperature, rainfall and relative humidity with Malaria, Typhoid and Tuberculosis especially in this study area. It is this gap in knowledge that this study intends to fill. Thus, this study attempted to answer the following questions:

1. What is the pattern of occurrence of temperature, rainfall and relative humidity in the study area?
2. What is the pattern of occurrence of cases of malaria, typhoid and tuberculosis in the study area?
3. What is the effect of temperature, rainfall and relative humidity on the occurrence of these diseases?
4. Is there seasonality in the occurrence of malaria, typhoid and tuberculosis in the study area?

1.3 AIM AND OBJECTIVES

The aim of this study was to examine the effect of rainfall, temperature and relative humidity on the occurrence of Malaria, Typhoid and Tuberculosis in Onitsha North Local Government area of Anambra State from 2004 to 2013.

This research aim was achieved through the following objectives which are to:

- i. determine the pattern of occurrence of rainfall, temperature and relative humidity between 2004-2013 in the study area.
- ii. determine the pattern of distribution of cases of malaria, typhoid and tuberculosis in the study area for the same period.
- iii. determine the pattern of distribution of cases of malaria, typhoid and tuberculosis in the study area.
- iv. determine the seasonality of malaria, typhoid and tuberculosis in the study area.

1.4 RESEARCH HYPOTHESIS

The hypothesis for this study is that there is no significant relationship between weather elements (rainfall, temperature and relative humidity) and the occurrence of malaria, typhoid and tuberculosis in the study area.

1.5 SCOPE OF THE STUDY

This study examined the effects of rainfall, temperature and relative humidity on the occurrence of malaria, typhoid and tuberculosis in Onitsha North Local Government Area of Anambra State from 2004 to 2013. It is concentrated more in the inland Onitsha North local

government area because this is the area where a large proportion of the population is concentrated and also where most of the hospitals are situated. This study focused on some selected hospitals in the study area which have records of up to 10 years (2004 to 2013) of the common diseases in the study area because most of the hospitals do not have complete hospital records of up to 10 years.

1.6 JUSTIFICATION OF THE STUDY

Weather has profound effect on human health and well-being. The importance of determining the role of weather in human health cannot be understated. Although there has been remarkable progress in medical science, reports of large increases in mortality during heat and cold waves are usually more common in developing countries because they have the lowest coping capabilities due to underdevelopment and poverty. It is good to know the climatic conditions that favour the persistence of the vectors that transmit most of the diseases in order to know the best time to carry out mitigation measures. This study would show the role if any weather elements play in the prevalence of some diseases. This study also serves as a source of enlightenment/additional information to fellow researchers, health workers, policy makers and the general public on the season in which certain diseases are more prevalent so as to check the

spread of these diseases as well as reduce mortality rate in Onitsha North local government area of Anambra state.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Worldwide, there is an apparent increase in prevalence of many infectious diseases which reflects the combined impacts of rapid demographic, environmental, social, technological and other changes in our ways-of-living. Climate change will also affect infectious disease occurrence. Rainfall can influence the transport and dissemination of infectious agents, while temperature affects their growth and survival, (Bouma and Van der Kaay, 1996). In fact, warmer or wetter conditions have enabled the spread of a great range of infectious diseases from their endemic regions to newer ones, (Robert, 2012).

As emphasized by Randolph(2008), Evengard and Sauerborn(2009), any increase in disease occurrence can be due to multiple factors. The factors that are most important are not always easy to determine. For infectious mononucleosis for example, which is caused by EB herpes virus and spreads from person to person by an oropharyngeal route, increasing ambient temperatures are thought to encourage higher than normal outdoor activity and social interactions, (Hubalek , 2005) which may then increase virus transmission. Several researches have suggested that climate can affect infectious disease patterns because disease agents (viruses, bacteria, and other parasites) and their vectors (such as insects or rodents) are clearly sensitive to temperature, moisture, and other ambient environmental conditions, Appawu, Owusu-Agyei, Dadzie, Asoala, Anto, Koram, Rogers, Nkrumah, Hoffman and Fryauff (2004); Ameneshewa and Service(1996); Burkot and Graves (1995) and the bites a person can receive per unit time are dependent on seasonal changes in climatic variables.

All climate and weather variables have some influence on human health, Stijn, Quynh, Hieu and Luc (2010); Abrignami, Carrao, Biondo, Renda, Braschi, Novo, Girolamo, Braschi and Novo (2009); Kriszbacher, Bodis, Csoboth and Boncz (2009). This chapter looked at the historical evidence of the relationship between climatic conditions and the occurrence of diseases, the effect of climate change on infectious diseases, how the diseases reacts to the various weather elements as well as the seasonality of the three diseases.

2.2 HISTORICAL EVIDENCE OF THE RELATIONSHIP BETWEEN CLIMATIC CONDITIONS AND THE OCCURRENCE OF DISEASES

There is much evidence of associations between climatic conditions and infectious diseases. Humans have known that climatic conditions affect epidemic diseases from long before the role of infectious agents was discovered, late in the nineteenth century. Roman aristocrats retreated to hill resorts each summer to avoid malaria. South Asians learnt early that, in high summer, strongly curried foods were less likely to cause diarrhea, (Bouma and van der Kaay, 1996). Climate variability may also affect outbreaks of infectious diseases (Epstein, 2010). At the moment, a warming climate, combined with widespread rapid ecological changes, is thought to have a stimulating change in disease patterns which affects humans in three major ways. These are; creation of ideal conditions for infectious disease outbreaks, increased potential for spread of vector borne diseases, which exposes millions of people to new health risks and diseases, and lastly, the hindrance of future efforts to control the spread of diseases across regions (Robert, 2012).

Scientists postulate that changes as a result of extreme weather conditions in some regions may bring about a drastic shift in the numbers of pests and disease vectors, leading to increased rates of transmission. This is because the rates of reproduction, spread and bites in many pests depends on weather patterns, and are usually high in warmer and wetter conditions. Warming increases the number of pests and micro-organisms due to the creation of optimal circumstances for both metabolism and reproduction at the interface of temperate conditions. This is directly correlated to the transmission and spread of diseases (Robert, 2012).

The association between the North Atlantic Oscillation (NAO) and the annual incidence rate of 13 viral, bacterial, and protozoan human diseases in the Czech Republic from 1951 to 2003 was investigated by Hubálek in 2005. According to this analyses, toxoplasmosis and

infectious mononucleosis were significantly and positively correlated and leptospirosis was negatively correlated with the NAO. For toxoplasmosis, it was proposed that the warmer winter associated with a positive NAO, lagged one year (meaning it occurred one year later), this would enhance populations of rodents, the intermediate hosts of the protist *Toxoplasma gondii*. For leptospirosis, higher precipitation in negative NAO years, lagged two years, would result in increasing populations of field rodents, the main reservoir of the bacteria *Leptospira interrogans* (Hubálek, 2005). A similar conclusion was reached for Hantavirus outbreaks in the USA in relation to El Niño (ENSO), with heavy rains or warm winters boosting mast seeding and thus favoring rodent populations, the reservoirs of hantavirus Engelthaler, Mosley, Cheek, Levy, Komatsu, Ettestad, Davis, Tanda, Miller, Frampton, Porter and Bryan (1999). Similar associations were also found for Hantavirus in Belgium Tersagoa, Verhagen, Servais, Heyman, Ducoffre and Leirs (2009). Hantavirus outbreaks in northern Europe were associated with a negative spring NAO with two years lag, which is in agreement with the findings of Tersagoa *et al.*, (2009) in Belgium. Heavy rains or warm winters and springs boost mast seeding and, with a certain time lag, favor rodent populations as reservoirs of Hantavirus.

Evidence of changes in influenza risk attributable to climate variability comes from Choi, Christakos and Wilson (2006), who found a lower mortality risk due to influenza during El Niño events compared to periods of normal weather. Sultan, Labadi, Guégan and Janicot (2005) showed that climate variability can also affect the occurrence of meningococcal meningitis, with a correlation found between the onset of meningococcal meningitis epidemics and the winter maximum of an atmospheric index. More recently, historical analyses have shown that the risk of a malaria epidemic increased approximately five-fold during the year following an El Niño in

this region (Bouma and Van der Kaay, 1996). Further, the risk of an epidemic is greater in a year in which excess rain occurs in critical months.

2.3 CLIMATE CHANGE AND INFECTIOUS DISEASES

Although climate change is a global phenomenon, its effects vary by location, making regional studies of potential impacts important. Extreme weather events are becoming more intense, more frequent and having impact on infectious disease as the world [climate changes](#) (Epstein, [Colwell](#), Gubler, Hall and Reiter, [1998](#); [Adeyemi, 2000](#); [Epstein, 2002](#)). Global [climate change](#) is a major contributor of infectious diseases, although their spreads are multi-causal. In Europe, some studies have provided important insights into the consequences of climate change on infectious diseases and evidence for resulting epidemiological changes in individual diseases, such as bluetongue; a disease of ruminants caused by a virus carried by mosquitos, midges etc (Purse, Mellor, Rogers, Samuel, Mertens and Baylis, 2005). Despite a limited knowledge primarily focused on vector-borne pathogens(Lafferty, 2009; Semenza and Menne, 2009; Epstein, 2010.), climate change is commonly predicted to impact the transmission of infectious diseases and their geographical distribution, (McMichael, Woodruff and Hales, 2006; Senior, 2008). This may be due to the impact of changes in mean temperature or rainfall, (Baylis, Mellor and Meiswinkel, 1999) and has been illustrated through statistical evaluation of pathogen dynamic trends and shifts in climatic factors (Paz, Bisharat, Paz, Kidar and Cohen, 2007; Pascual, Cazelles, Bouma, Chaves and Koelle, 2008).

Research findings estimates that between 150,000 and 160,000 excess deaths are caused every year by human-enhanced [climate change](#) ([WHO, 2003](#); [Doyle, 2003](#); [Bate, 2004](#)). [Bate](#)

[\(2004\)](#) stated that some of these deaths occurred in the developed world but the majority was attributed to the developing world. Diseases such as malaria, yellow and dengue fevers have increased in frequency and distribution in the last decade due to [climate change](#), the number of excess deaths is projected to have doubled by 2020 ([Attaran](#), Donald, Chris and Wenceslaus, [2000](#); [Reiter](#), 2008; [Bate](#), 2004).

2.4 SENSITIVITY OF INFECTIOUS DISEASE TO WEATHER ELEMENTS

2.4.1 Sensitivity of Infectious Diseases to Temperature

Ati (2002) described temperature as the degree of sensible heat or cold within the atmosphere. Extreme temperatures often are lethal to the survival of disease-causing pathogens but incremental changes in temperature may exert varying effects. Where a vector lives in an environment where the mean temperature approaches the limit of physiological tolerance for the pathogen, a small increase in temperature may be lethal to the pathogen. Alternatively, where a vector lives in an environment of low mean temperature, a small increase in temperature may result in increased development, incubation and replication of the pathogen (Lindsay and Birley, 1996; Bradley, 1993). Temperature may modify the growth of disease carrying vectors by altering their biting rates, as well as affect vector population dynamics and alter the rate at which they come into contact with humans. Finally, a shift in temperature regime can alter the length of the transmission season (Gubler, Reiter, Ebi, Yap, Nasci and Patz, 2001).

Increasing temperatures may lengthen the seasonality or alter the geographical distribution of water-borne diseases. In the marine environment, warm temperatures create favourable conditions for red tides (blooms of toxic algae) which can increase the incidence of shellfish poisoning (Epstein, 1993). Increasing sea surface temperatures can indirectly influence the viability of enteric pathogens such as *Vibrio cholerae* by increasing their reservoir's food supply (Colwell, 1996). Ambient air temperatures also have been linked to hospital admissions of Peruvian children with diarrhoeal disease (Checkley *et al.*, 2000).

Disease carrying vectors may adapt to changes in temperature by changing geographical location. An emergence of malaria in the cooler climates of the African highlands may be a result of the mosquito vector shifting habitats to cope with increased ambient air temperatures (Cox, Craig, Le Seieur and Sharp 1999). Another possibility is that vectors undergo an evolutionary response to adapt to increasing temperatures. There is recent evidence to suggest that the pitcher-plant mosquito (*Wyeomia smithii*) can adapt genetically to survive the longer growing seasons associated with climate change. Bradshaw and Holzapfel, (2001) demonstrated this by documenting a change in the photoperiodic response between two different time periods in two populations of pitcher-plant mosquitoes. The change in response was correlated to a marked genetic shift within the mosquito species.

A greater degree of micro evolutionary response was associated with mosquito populations inhabiting higher latitudes. The hypothesis is that because these populations have greater selection pressure they have also a greater ability to evolve genetically. Although the study was limited to one specific species of mosquito, it suggests that other mosquitoes, perhaps disease carrying vectors, may undergo an analogous microevolution which would allow

adaptation to altered seasonal patterns associated with global climate change (Bradshaw and Holzapfel, 2001).

2.4.2 Sensitivity of Infectious Diseases to Precipitation

Variability in precipitation has direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. In addition, increased precipitation may support a growth in food supplies which in turn support a greater population of vertebrate reservoirs. Unseasonable heavy rainfalls may cause flooding and decrease vector populations by eliminating larval habitats and creating unsuitable environments for vertebrate reservoirs. Alternatively, flooding may force insect or rodent vectors to seek refuge in houses and increase the likelihood of vector-human contact. Epidemics of leptospirosis, a rodent-borne disease, have been documented following severe flooding in Brazil (Ko, Reis, Cibebe, Dourado, Johnson Jr, Riley, and the Salvador Leptospirosis Study Group, 1999). In the wet tropics unseasonable drought can cause rivers to slow, creating more stagnant pools that are ideal vector breeding habitats.

Heavy rains can contaminate watersheds by transporting human and animal faecal products and other wastes in the groundwater. Evidence of water contamination following heavy rains has been documented for cryptosporidium, giardia, and *E.coli* (Parmenter, Yadav, Parmenter, Ettestad and Gage 1999; Atherholt, Le Chevallier, Norton, and Rosen 1998). This type of event may be increased in conditions of high soil saturation due to more efficient microbial transport (Rose, Epstein, Lipp, Sherman, Bernard and Patz, 2001). At the other

extreme, water shortages in developing countries have been associated with increases in diarrhoeal disease outbreaks that are likely attributed to improper hygiene (WHO, 1999).

2.4.3 Sensitivity of Infectious Diseases to Humidity

Humidity can greatly influence transmission of vector-borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions. Saturation deficit (similar to relative humidity) has been found to be one of the most critical determinants in climate/disease models, for example, dengue fever (Focks, Haile, Daniels and Mount 1995; Hales, de Wet, Maindonald and Woodward, 2002) and Lyme disease models (Mount, Haile and Daniels, 1997).

2.5 SEASONALITY OF INFECTIOUS DISEASES

Disease pattern may result from increased likelihood of transmission due to indirect social or behavioural adaptations to the cold weather such as crowding indoors. Another possibility is that it may be attributed directly to pathogen sensitivities to climatic factors such as humidity. In addition to influenza, several other infectious diseases exhibit cyclic seasonal patterns, which may be explained by climate. In diverse regions around the world, enteric diseases show evidence of significant seasonal fluctuations. In Scotland, campylobacter infections are characterized by short peaks in the spring (Colwell and Patz, 1998). In Bangladesh, cholera outbreaks occur during the monsoon season (Colwell, 1996). In Peru,

cyclospora infections peak in the summer and subside in the winter (Madico, McDonald, Gilman and Cabrera, 1997).

Similarly, some vector-borne diseases (e.g. malaria and dengue fever) also show significant seasonal patterns whereby transmission is highest in the months of heavy rainfall and humidity. Epidemics of other infections (e.g. meningococcal meningitis) tend to erupt during the hot and dry season and subside soon after the beginning of the rainy season in sub-Saharan Africa. Weather and climate can influence host defenses, vectors, pathogens and habitat ([Epstein, 2002](#)). Temperature and rainfall are climatic causal factor of diseases and a small change in temperature and rainfall are unlikely to have a significant impact on the spread of disease ([Epstein et al, 1998](#); [Bate, 2004](#)). [Small, Hay and Goetz, \(2003\)](#) found that rainfall and relative humidity, rather than temperature, was the primary forcing factor in malaria transmission trends in Africa during most of the twentieth century. Rainfall patterns can influence the transport and dissemination of infectious agents while temperature can affect their growth and survival ([Rose et al, 2001](#)).

2.5.1 Seasonality of Malaria

Malaria is probably the vector-borne disease most sensitive to long-term climate change (WHO, 1996). Malaria varies seasonally in highly endemic areas. The link between malaria and extreme climatic events has long been the subject of study in the Indian subcontinent. Early in the twentieth century, the Punjab region experienced periodic epidemics of malaria. Irrigated by five rivers, this geographical plains region borders the Thar desert. Excessive monsoon rainfall and resultant high humidity were clearly identified as major factors in the occurrence of

epidemics through enhancement of both the breeding and life-span of mosquitoes (Christophers, 1911), for example; early last century, the river-irrigated Punjab region experienced periodic malaria epidemics. Excessive monsoon rainfall and high humidity was identified early on as a major influence, enhancing mosquito breeding and survival. Recent analyses have shown that the malaria epidemic risk increases around five-fold in the year after an El Niño event (Bouma and van der Kaay, 1996).

Malaria is known to be endemic in the tropic ([Evengard and Sauerborn, 2009](#)). Its common symptoms are headaches, weakness, fever, aches, pains, high body temperature, bitterness of the mouth, loss of appetite, nausea and vomiting. It is a serious disease affecting children and adults but its consequences are graver among children and pregnant women ([UNICEF, 2000](#); [Van-Geertruyden, Thomas, Erhart and Alessandro, 2004](#)). Available records show that at least 50% of the population of Nigeria suffers from at least one episode of malaria each year and malaria accounts for over 45% of all out-patients visits ([Federal Ministry of Health, 2001](#); [Ejezie, Ezednachi, Usanga, Gemade, Ikpatt and Alaribe, 1991](#)). It was reported that malaria prevalence (notified cases) in 2000 was about 2.4 million ([Federal Ministry of Health, 2001](#)) and responsible for an estimated average annual reduction of 1.3% in economic growth for the countries with the highest burden, Nigeria inclusive ([Onwujekwe, Chima and Okonkwo, 2000](#)). Therefore, it imposes a great burden on the country in terms of pains and trauma suffered by its victims as well as loss in outputs and cost of treatments ([Onwujekwe, Hanson and Fox-Rushby, 2004](#)). The spread of infectious diseases such as malaria is multi-causal but could be influenced by global [climate change](#) or climatic variability directly or

indirectly ([Patz, 2000](#); [Woodruff](#), Guest, Garner, Becker, Lindesay, Carvan and Ebi, 2002; [Evengard and Sauerborn, 2009](#)).

The findings of the study of [Ceccato](#), Ghebremeskel, Jaiteh, Graves and Levy ([2007](#)) in part of Eritrea and that of [Guofa](#), Minakawa, Andrew, Githeko and Guiyun, ([2004](#)) study in East Africa Highland were both similar where they observed a relationship between malaria incidence and climatic anomalies (temperature and rainfall). Weather and climate can influence host defenses, vectors, pathogens and habitat, nevertheless, disease such as malaria could be spread even without excessive rainfall and temperature but extreme rainfall and temperature increases the likelihood of its high morbidity ([Reiter, 2001](#); [Epstein, 2002](#); [Bate, 2004](#)). Nevertheless, examining climatic variables associated with infectious diseases will go a long way in anticipating associated future risks and direct our attentions at observations ([Epstein, 2002](#)).

A topic of growing concern, and debate, is the role of climate change in variability and trends in malaria, ([Epstein *et al*, 1998](#); [Lindsay and Martens, 1998](#); [Hunter, 2003](#); [Matsuoka and Kai, 1994](#); [Leaf, 1989](#)). Several countries and regions have reported emerging or growing threat of malaria due to change in climate, ([Patz, Epstein, Burke and Balbus, 1996](#); [Githeko, Lindsay, Confalonieri and Patz 2000](#); [Tanser, Brain and David, 2003](#); [Martens, Niessen, Rotmans, Jetten and McMichael, 1995](#); [Caminade, Ndione, Kebe, Jones and Danuor, 2010](#)). While deaths due to malaria depend on a number of factors, ([Snow, Craig, Deichmannle and Sueur 1999](#); [Craig, Snow and Sueur, 1999](#); [Macdonald, 1958](#)) like vector control, access to adequate medical facilities and immunological history of the people, infections can be considered to depend primarily on abundance of mosquito vector and exposure of the host to bites and rate of transmission.

A quantitative delineation of the role of weather variables in malaria load can enable the design of pro-active mitigation based on vector control; implementation of such pro-active vector control is becoming increasingly important in view of reported resistance of mosquitoes to insecticides, (Davidson and Zahar, 1973). At the same time, such quantitative relations between weather variables and malaria can enable reliable projection of vulnerability in a changed climate.

The importance of meteorological variables in genesis and survival of mosquito have been known for a long time, although the relative roles of these variables and various aspects are still being investigated. However, fairly sharp and well defined ranges of meteorological variables, especially temperature, are required for genesis and survival of malaria vector, although these thresholds also depend on the mosquito species, (Paaijmans, Read and Thomas, 2009; Koenraadt, Paaijmans, Githeko, Knols and Takken, 2003; Paaijmans, Wandago, Githeko and Takken 2007; Leeson, 1939; Paaijmans, Imbahale, Thomas and Takken, 2010). For example, there are well known thresholds of minimum and maximum of temperature for vector genesis and survival. Each weather variable has a range in which it affects the mosquito genesis and survival; a temperature above 16°C is required for breeding and development of the aquatic stages of Anopheline mosquitoes in the Tropics. Similarly, experiments indicate a threshold of minimum temperature between 16°C and 19°C for the development of *Plasmodium falciparum* (PF) malaria parasite.

Temperature affects the rate of reproduction of the pathogens, and thus plays important role in the survival and transmission the vector (Gillett, 1974). Temperature is also known to affect the gonotrophic cycle (physiological process consisting of digestion of blood-meal and

development of ovaries), and longevity. However, other weather variables like rainfall and humidity also play important roles (Gillett, 1974; Blanford, Blanford, Crane, Mann and Paaijmans, 2013). For example, amount, intensity as well as duration of rainfall all play important roles in the dynamics of vector population. Besides, other environmental variables like land use and land cover also affect vector dynamics, (Paaijmans and Thomas, 2011; Paaijmans, Imbahale, Thomas and Takken, 2010).

Rainfall can significantly reduce the vector survival by flushing the larval mosquitoes out of their aquatic habitat, (Paaijmans, Wandago, Githeko and Takken, 2007). It can be logically assumed that reduced larval survival will also lead to a smaller population of adult mosquitoes. Both dryness and rainfall can influence larval survival significantly, as shown by experiments with simulated dry conditions, (Koenraadt, Paaijmans, Githeko, Knols and Takken 2003; Paaijmans, Imbahale, Thomas and Takken, 2010). Similarly, transmission can be inhibited by development time of the pathogen larger than the life span of the insect, (Leeson, 1939). Higher temperature, on the other hand, can lead to quicker maturity leading to higher number of off springs during the transmission period, (Paaijmans, Imbahale, Thomas and Takken, 2010). Thus vector abundance can be assumed to be primarily determined by the climate (average weather regime) and the weather (variability around the climate) of the region (Paaijmans, Read and Thomas, 2009; Koenraadt, Paaijmans, Githeko, Knols and Takken, 2003; Paaijmans, Wandago, Githeko and Takken, 2007; Leeson, 1939; Paaijmans, Imbahale, Thomas and Takken, 2010; Gillett, 1974; Blanford *et al*, 2013; Paaijmans and Thomas, 2011).

It is also known that the effect of environmental parameters on vector population can be highly location-specific. The phenology and population dynamics of mosquito can vary

significantly with altitude; a study based on weekly rainfall intensity in the Lake Victoria basin showed significant differences in larval abundance with altitudes, (Imbahale, Paaijmans, Mukabana, Lammeren and Githeko, 2011). It was found, for example, that for northern Australia, determination of the periodicity and the amplitude of mosquito population (abundance peaks) required consideration of the frequency and the amplitude of the tides, (Gill, 1920); a flood plain or a forested region is likely to require very different considerations. Over India, several studies have shown relationship between weather variables and malaria, (Gill, 1920; Gill, 1921; Dhiman, Sharmila and Dash, 2008). India with its complex climatic heterogeneity, growing population, land-use and urbanization poses a unique challenge to identify role of climate change in malaria load, (Mohapatra, Narain, Prakash, Bhattacharyya and Mahanta 2001; Tiwari, Ghosh, Ojha, Dash and Raghavendra, 2010; Kiszewski and Teklehaimanot, 2004). In particular, a region can experience both decrease and increase in malaria prevalence as the meteorological variables move in or out of the genesis window.

A robust and reliable assessment of vulnerability to malaria due to climate change require quantitative, validated models of malaria epidemiology that involve all the relevant weather variables; assessments based on the trend of a single meteorological variable do not have much relevance. While the role of meteorological variables in malaria has been well recognized, and several attempts have been already made to use weather-driven models for malaria, (Parham and Michael, 2010; Hoshen and Morse, 2004), most methods have used only a single meteorological variable or time-averaged (weekly/monthly mean) values to assess impact of climate change on malaria. However, dynamics of mosquito population (genesis as well as mortality) depends on daily variability of the weather variables, (Paaijmans, Imbahale, Thomas and Takken, 2010); in

general, this daily variability will be much higher than that in monthly-averaged variables. Thus, vector abundance, and hence impact of malaria, is likely to depend on the number of daily genesis windows.

Large changes in temperature can lead to reduction in the duration of gonotrophic cycle and in the extrinsic incubation period of malaria parasite and affect the rate of transmission, (Patz, Graczyk, Geller and Vittor, 2000). Similarly, possible changes in the immunology profile of a people due to factors like migration may also become important in the long term. However, most of the processes in the post-larval stages become less important if vector sanitation is carried out at the genesis sites. The framework and the methodology are quite generic and can be applied in any geographical location with required calibration.

In practice, several species of mosquito are responsible for malaria in India, (Sharma, Tyagi, Padhan, Adak and Subbarao, 2004; Singh, Nagpal, Sascena and Singh, 2004; Kumar, Sharma, Sumodan, Thavaselvam and Kamat, 1994; Vinayak, Biswas, Dev, Kumar and Ansari, 2003). The genesis and survival criteria may vary somewhat from species to species; similarly, the effects of local environmental conditions like run-off, land use and water stagnation may affect mosquito dynamics.

Githeko and Ndegwa, 2001) compared monthly climate and malaria data in highland Kakamega and found a close association between malaria transmission and monthly maximum temperature anomalies over three years (1997–2000). A strong correlation is found between both annual rainfall and the number of rainy days and the incidence of malaria in most districts of Rajasthan and in some districts in Gujarat (Akhtar and Michael, 1996). Hartman, Ebi,

McConnell, Chang and Weyant, (2002) used 16GCM future scenarios to study their effect on climate suitability for malaria in Zimbabwe. Using the MARA/ARMA model of climatic limits on *Anopheles* mosquitoes and *Plasmodium* parasites, the authors mapped the change in geographical distribution of endemic malaria. For all scenarios the highlands become more suitable for malaria transmission while the lowlands show varying degrees of change.

2.5.2 Seasonality of Typhoid

Typhoid is a serious disease, and is caused by a bacterium called *Salmonella typhi*. Typhoid causes high fever, loss of appetite, and sometimes a rash. If not treated, it can kill up to 30% of people who are infected. Typhoid in Africa is present in both rural and urban areas, though the risk is lower in the larger cities (Machault, Vignolles, Borch, Vounatsou, Pages, Briolant, Lacaux, and Rogier, 2011). This disease occurs with the change in temperature each year, viruses keep on modifying genetically and the virus is different every year leading to increase in frequency of vomiting and diarrhea (Bedi and Zhang, 2004).

There has been some suggestion that higher water temperatures will lead to more prolonged survival of pathogens in the environment. Higher temperature can affect both the distribution of the vector and the effectiveness of pathogen transmission through the vector. Gubler, Reiter, Ebi, Yap, Nasci and Patz, (2001) listed a range of possible mechanisms whereby changes in temperature impact on the risk of transmission of vector borne diseases:

- i. Increase or decrease in survival of vector.
- ii. Changes in rate of vector population growth.
- iii. Changes in feeding behaviour.
- iv. Changes in susceptibility of vector to pathogens.

- v. Changes in incubation period of pathogen.
- vi. Changes in seasonality of vector activity and
- vii. Changes in seasonality of pathogen transmission.

The impacts of heavy rainfall events, flooding, and increased temperature are also associated with high counts of indicator bacteria in river waters and marine waters (Crowther, Kay and Wyer, 2001). Typhoid and paratyphoid fever (TPF) has been controlled effectively in Europe and North America, but it remains a serious public health problem in Asia, Africa, and Latin America (Vollaard, Ali, Van Asten, Widjaja, Visser and Surjadi, 2004). Ingestion of contaminated water and food is the most common route of TPF transmission (Maskalyk, 2003), for example, heavy rainfall has been associated with an increase in outbreaks of enteric pathogens, usually due to the contamination of water.

Many social factors, especially economic development level, health facilities, and living conditions may influence the incidence of TPF (Kelly-Hope, Alonso, Thiem, Canh do, Anh, and Lee 2007). Environmental factors, such as climate, have also been investigated to assess their influence on water/food-borne infections (Shuman, 2010). Many meteorological factors can affect bacterial contamination of food and/or water. For example, heavy rainfall has been associated with an increase in outbreaks of enteric pathogens, usually due to the contamination of water supplies (McMichael, Woodruff and Hales 2006). As contaminated water or food is the most common mode of TPF transmission, meteorological factors may influence the incidence rate and contribute to outbreaks of TPF (Zhang, Bi and Hiller 2010). Typhoid fever which is otherwise known as enteric fever is a disease prevalent in the world over and continues to be a

major public health concern in most **developing countries** of the world, especially Africa ([Mizel and Bates, 2010](#)).

2.5.3 Seasonality of Tuberculosis

Tuberculosis (TB) is the second leading cause of death among adults worldwide. It is equally reported that 13 million people suffer from active TB infection worldwide. These data portray a worrisome global situation of TB but much more in developing countries where standard of living is low and health services are grossly inadequate. Besides the fact that the tropical countries suffer from high tuberculosis prevalence, they also show an increasing trend of the disease (Prabhakar, 1996).

TB infection is caused by the bacillus, *Mycobacterium tuberculosis* (WHO Global TB Report, 2010). It spreads through the inhalation of droplets from an infected person's sneeze or cough by others people. Although the body immune system is capable of restraining the disease, if the immune status is low and the disease becomes active, the respiratory system and other body organs are subsequently attacked. Global attention targets early detection of the disease, development of effective drugs and combating the emergence of multi-drug resistant strains. In spite of this huge commitment, TB control poses challenges till today owing to its opportunistic association with HIV infection and the emergence of drug resistant strains among other things (WHO Global TB Report, 2010; Dye and Espinal 2001; World Health Organization, 2004b). Hence the need to give substantial attention to components that could feed into strategies for prevention.

It is already known that weather variables influence the occurrence of diseases; the influence may be on the reproduction and survival of pathogen or the carriers of pathogens, (Wilkinson, 2006). Moreover, weather conditions may encourage the exposure of human to high concentration of pathogens characteristic at places where population (patients and healthy individuals) congestion is found (Checkley *et al*, 2000). According to Nakaji *et al*, (2004) and Braga, Zanobetti and Schwartz (2002), mortality cases arising from tuberculosis, other respiratory diseases, diabetes and heart diseases among others peaked during the cold time of year. In the mid- 90s, the Greater London recorded 150% increase in respiratory infections-related mortality at winter than summer, Kovats, Hajat and Wilkinson (2004). Comprehensive results from 12 studies for the period from 1971 to 2006 from 11 countries around the world (South Western Cameroun, South Africa, India, Hong Kong, Japan, Kuwait, Spain, United Kingdom, Ireland, Russia and Mongolia) shows that the manifestation of tuberculosis has a variable seasonality peak with the most predominant peak during spring and summer seasons in all of the countries except South Western Cameroun and Russia, which found its risk of transmission of tuberculosis to be greatest during the winter months, (Fares, 2011).

Clinical cases of pulmonary and extra-pulmonary tuberculosis showed peak occurrence during the spring and summer seasons, (Fares, 2011). According to Nakaji *et al*,(2004) and Ford(1981), morbidity and mortality of respiratory diseases (including tuberculosis) were higher at winter period than summer. The plausible explanation of this apparent contradiction can be linked to the lag period of months between the infection of *M. tuberculosis* (possibly at winter) and clinical manifestation (during summer), Fares (2011). Influence of weather parameters is also considered to be possibly indirect and contextual (Maes, Stevens, Scharpe, Bosmans, De

Meyer and Dhondt, 1994); affecting human activities, nutrition status, body immune system and exposure to beneficial sun rays.

Tuberculosis is increasingly becoming a worldwide problem because of the advent of HIV and AIDS, poor living conditions (Kamuolratanakul, Sawwert and Kongsin, 1999) and the emergence of multi-drug-resistance (MDR) TB for which treatment is beyond the reach of most people in African countries. One third of the world's population is exposed to TB and it is responsible for approximately three million deaths each year. It is estimated that eight million new cases of TB occur each year and Africa has the highest incidence rate (World Health Organization, 2002).

Seasonal fluctuation of TB has been reported in some countries (Leung, Yew and Chan, 2005; RAos, GarcAa, SAjnchez and PAcrez, 2000; Schaaf, Nel, Beyers, Gie , Scott and Donald, 1996; Michael, Lennox and Nwanyanwu, 2001), and data on the seasonality of TB that is available in most developing countries is inadequate. This is worsened by the lack of resources for diagnosis and treatment of TB. Hippocrates once said "Whoever wishes to investigate medicine properly should proceed thus: in the first place to consider the seasons of the year, and what effects each of them produces" (Michael, Lennox and Nwanyanwu, 2001).

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 THE STUDY AREA

3.1.1 Location and Size

Onitsha-North Local Government Area in Anambra State is situated between latitudes 06° 02' N and 06° 08' N and longitudes 06° 47' E and 06° 59' E. It serves as the gateway between southeastern and southwestern Nigeria. It has a land mass of 36.12km² and is bound by Idemili-North L.G.A to the east, to the west by River Niger, to the south by Onitsha-South L.G.As., and to the north by Oyi and Anambra-East L.G.A. Onitsha lies on the east bank of the Niger River just south of its confluence with the Anambra River (See Figures 3.1 and 3.2). It was founded by adventurers from Benin (nearby to the west) in the early 17th century, (Encyclopedia Britannica, 2014).

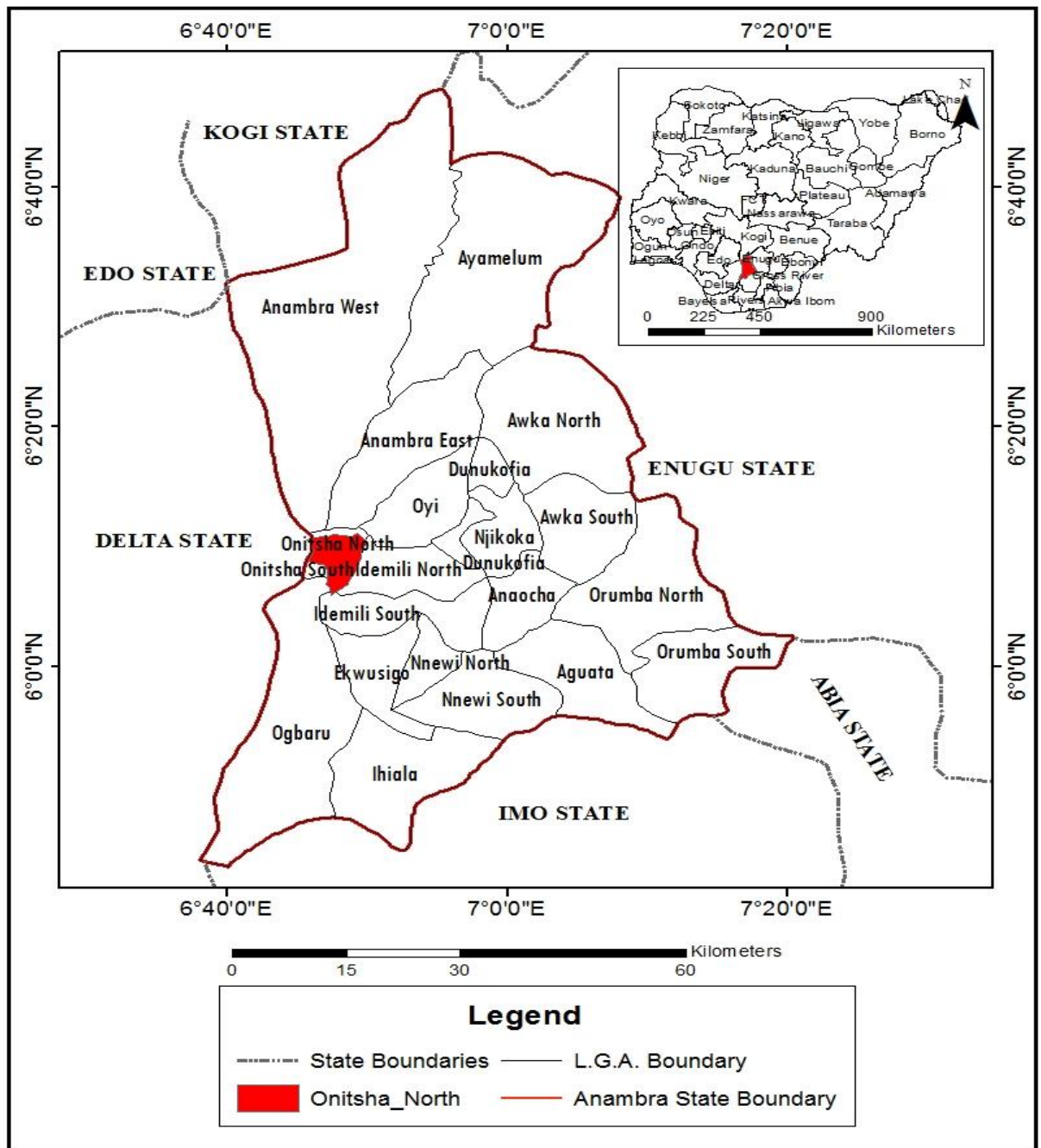


Figure 3.1 Location of Onitsha North in Anambra State.

Source: Adapted from Administrative Map of Anambra State.

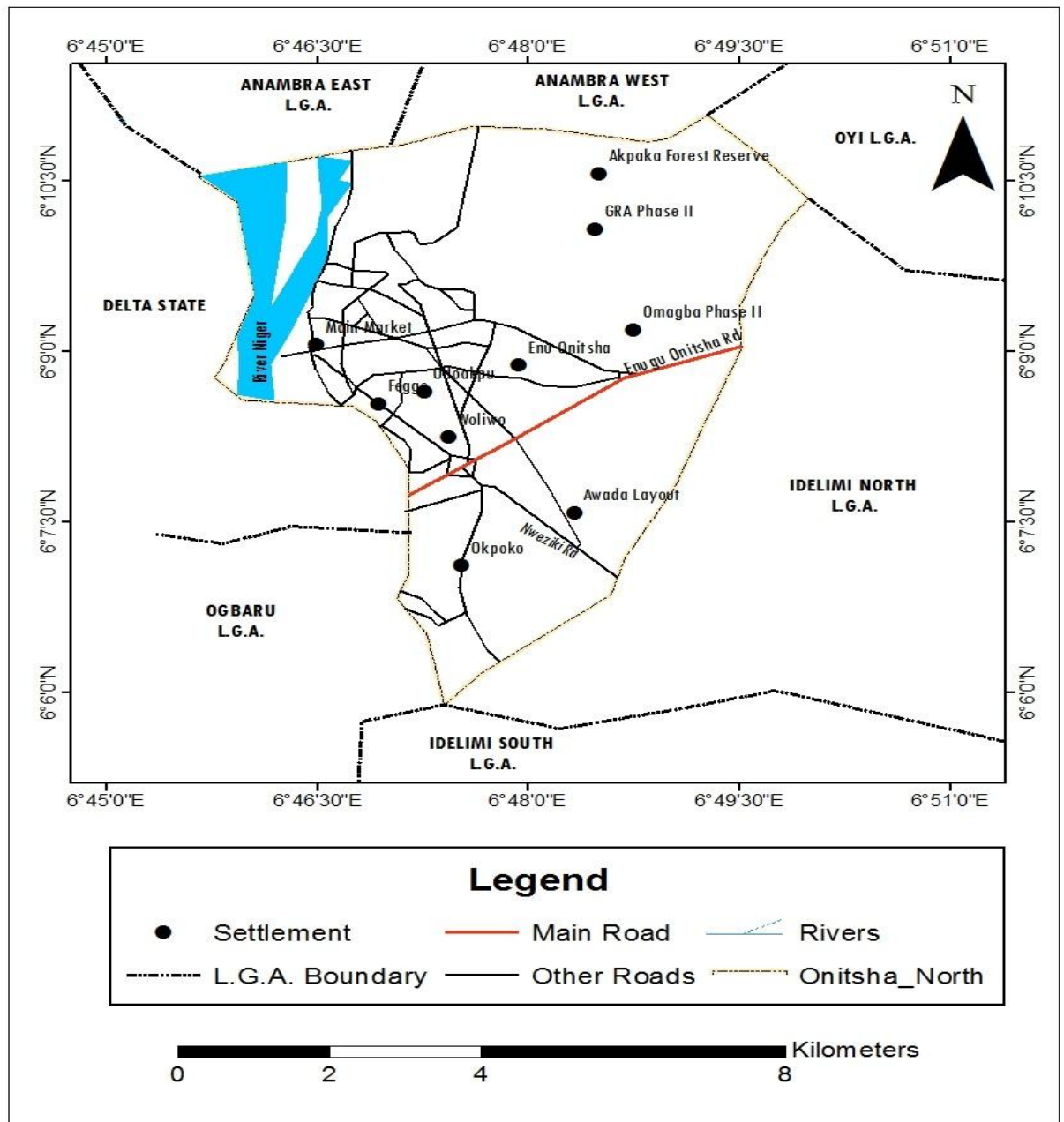


Figure 3.2 Map of Onitsha North Local Government Area.

Source: Adapted from Administrative Map of Anambra State.

3.1.2 Climate

Onitsha and its neighbouring towns are located in the transition area between the sub-equatorial and the tropical hinterland climatic belts of Nigeria. It lies within the tropical wet/dry climate referred to as 'Aw' in the Koppen Greigiger's system of climatic classification (Monanu, 1975). The climate here is influenced by two major trade winds: the warm moist south-west trade winds during the rainy season (April–October) and the north-east trade winds during the dry and dusty harmattan (November–March) period (United Nations Human Settlements Programme, 2012). This has led to the different seasonal pattern experienced which in turn should have an influence on the rate at which different diseases spread.

In Onitsha, temperatures are generally high, between 25 and 27 degrees Celsius, with minimum temperatures experienced between December and March and maximum temperatures between June–September. Annual rainfall averages about 1,850 millimeters per annum. Most of the rain falls between mid-March and mid–November. Relative humidity is generally high throughout the year, between 70 to 80 percent. The highest figures are experienced during the wet season and the lowest during the dry season (United Nations Human Settlements Programme, 2012).

3.1.3 Relief and Drainage

The land scape of Onitsha is a low land. The eastern part of the town is a bit hilly while the rest is claimed by the river Niger which lies on the western part of the town. The inland town is on high grounds, this upland area varies between 150 and 240 meters in height which is dissected by a number of small streams draining into the Niger, and more recently developed

areas of Odoakpu and Otu are on lower grounds. Fegge and the unauthorized areas of Okpoko are situated within the flood plains (Elekwa 1991).

The area is drained mainly by the Niger River and its many tributaries, notably Anambra (which lends the state its name), Nkissi, and Idemili Rivers, all draining into the Niger. The Anambra River is the largest of all the tributaries of the Niger, south of Lokoja, the confluence of Benue River with the Niger (United Nations Human Settlements Programme, 2012).

3.1.4 Soils and Vegetation

Around Onitsha and on the banks of the Niger River is a wide plain of alluvium. There are also sandy and loamy soils around Nkpor and Ogidi. The porous nature of the soils dictates special consideration for foundation and landscape design and nature conservation.

The vegetation of this region is light forest interspersed with tall grasses. The trees are not too tall and include both hardwood and softwood varieties; domesticated trees such as the mango, palm tree, guava, orange, and almond are found. Much of the natural vegetation has been felled and the land utilized for development (United Nations Human Settlements Programme, 2012).

3.1.5 Geology

Onitsha and its neighboring towns are situated within the vast sedimentary basins of the Niger-Benue trough of the upper middle Eocene strata known as the Bende-Ameke formation, which comes very close to River Niger. Within this area, there are large areas of alluvium from the Quaternary period. The geology of the area is characterized by the Orlu cuesta which

terminates at the Niger River bank. It provides a stretch of well-drained, healthy site in the flood plains of the River Niger. Such favorable site at the meeting point of two contrasting regions east and west of the Niger, and the Niger itself, which provides a link with the savanna zone to the north and the forest and delta region to the south, enabled the area to develop as an important commercial center (United Nations Human Settlements Programme, 2012).

3.1.6 Population

Anambra State has a population of 4,182,032 people with an average density of 633 persons per sq. km. The population of Onitsha North in 2006 was estimated to be 390501 with an average population density of 3,771 persons per sq. km, (NPC, 2006).

3.1.7 Human Activities

The major occupation in Onitsha is trading with few people mostly residing in the rural part of Onitsha engaging in fishing. The chief commercial products grown in Onitsha are nuts, corns, fruits and vegetables. Other products which form an integral part of trade in Onitsha include tires, petroleum products, nails and bearings. They are largely manufactured in and around the city. There is relatively high concentration of trade/commercial activities, artisans and small scale manufacturing in most urban areas of the study area. There are a lot of large scale manufacturing industries in the state such as the breweries, textile and soft-drink bottling companies(United Nations Human Settlements Programme, 2012).

3.1.8 Environmental Challenges

The increasing urban activities and population explosion has resulted in widespread clearing of vegetation covering farmlands and wood lands throughout the area. Due to Onitsha's peculiar topography, during rainy seasons, Onitsha always experiences heavy rainfall due to its nearness to River Niger. This gives rise to flooding in the coastal areas leading to destruction of lives and properties; hence erosion has become the greatest menace to the livelihood of this city's residents. According to Elekwa (1991), many development projects carried out in these areas were without regard to the environment and this poses potential health problems and other hazards such as flooding, congestion, confusion etc.

Environmental problems in Onitsha also arise from the inability of public sector authorities like the Onitsha Town Planning Authority and the Onitsha Local Government councils to enforce regulations governing land development, industrial emissions etc. Onibokun (1989) adduced reasons for their inability to include; “poor critical assumption in population projections which have often been extremely weak, and the inability of plans to be adjusted and/or refined in the light of changing conditions, such as the invasion and setting up of unused public spaces among other land uses”. These and other reason may contribute to the high rate of certain diseases such as malaria, tuberculosis etc. present in the study area.

3.2 METHODOLOGY

Reconnaissance survey was carried out in order to get familiar with the study area and to obtain the exact location of the hospitals mostly used by residents in the study area. Descriptive study was the research type used by the researcher.

3.2.1 Types and Sources of Data

Data (Hospital records, Climatic data) for this study were collected from secondary sources. The data were monthly record of temperature (minimum and maximum); rainfall and relative humidity from 2004 to 2013 for Onitsha. This was collected from Nigerian Meteorological Agency (NIMET) Anambra State office located in Awka. Medical records of cases of malaria, typhoid and tuberculosis for the corresponding years were obtained from the major hospitals in the area (because most of the hospitals in the study area do not have more than ten years continuous record of data).

3.2.2 Sampling Technique

Purposive non probability sampling technique was used for the study in order to determine the hospitals to be sampled. Thereafter, the following hospitals were selected; St Charles Borromeo Hospital, Onitsha General Hospital, Iyi Enu Missionary Hospital, St Patricks Hospital and Maternity, which serve as representatives of the various types of hospitals in the Local Government Area based on ownership (Catholic Missionary, State Government owned, Anglican Missionary and Private Owned respectively). Bases on the reconnaissance study, the hospitals were chosen because they had the records of the reported cases of the diseases of interest for the period of study (2004-2013).

3.2.3 Presentation of Data

This was done using descriptive statistics. All the data collected were represented in a tabular form. The monthly mean for the climatic variables was also calculated.

3.2.4 Data Analysis

Objectives 1 and 2 were achieved by obtaining the mean of each of the individual variable involved for each year which was represented using a line graph. Trend line and linear trend line equations were displayed on the produced line graphs.

Objective 3 was achieved using Pearson Product Moment Correlation Co-efficient, which was used to measure the degree of relationship that exists between the variables of interest (rainfall, temperature and relative humidity/ malaria, typhoid and tuberculosis occurrences). Data was analyzed using IBM SPSS (version 20).

Objective 4 was achieved by getting the overall mean for each of the diseases and weather elements for the corresponding years which was calculated across the seasons and the result was presented in a bar graph. To account for the nature of seasonal variation of the weather elements and the diseases of interest for the corresponding years in the study, three seasons per annum were considered; hot-dry season (February-March), rainy season (April-October), cold-dry season (November-January).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results of various analyses aimed at revealing the pattern as well as the relationship between the weather elements of interest (Rainfall, Temperature and Relative Humidity) and some common diseases (Malaria, Typhoid and Tuberculosis) in Onitsha North Local Government Area, Anambra State for the period of 2004 to 2013.

4.2 TRENDS OF THE WEATHER ELEMENTS IN THE STUDY AREA

4.2.1 Trend in Rainfall Distribution (2004-2013)

Figure 4.1 shows the trend of rainfall in the study area for the period of ten years (2004-2013).

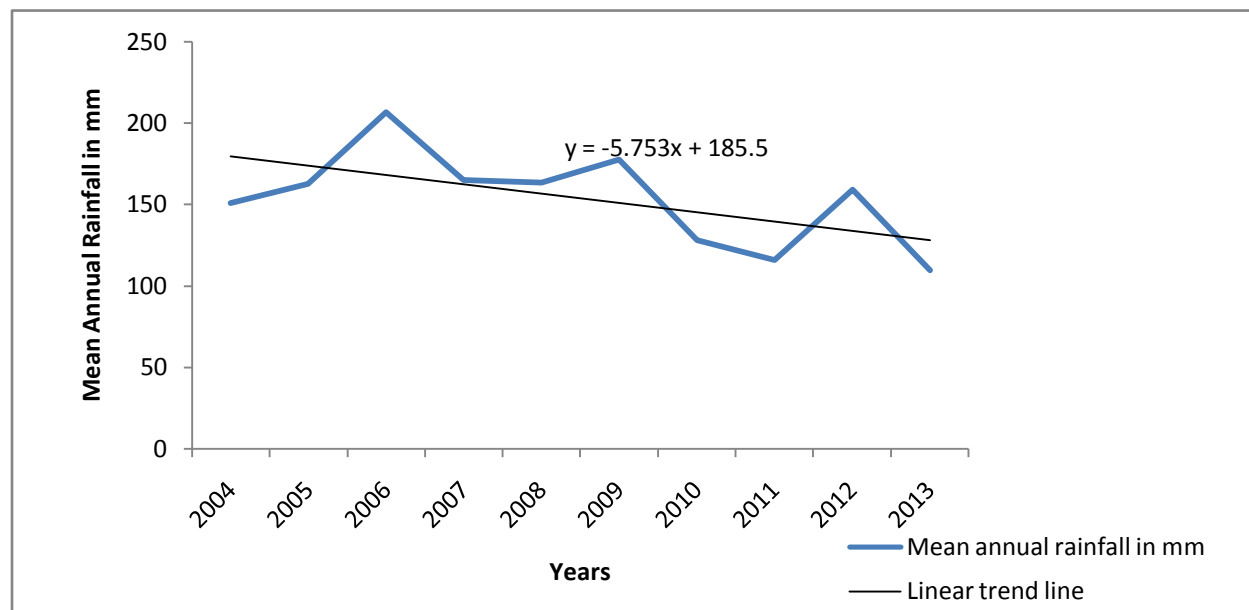


Figure 4.1: Trend of Rainfall in Onitsha North Local Government Area (2004-2013)

The trend in Figure 4.1 shows that rainfall in the study area has been fluctuating and there is a significant decreasing trend in the pattern of occurrence of rainfall as indicated by the linear trend line. The linear trend line equation $y = -5.7539x + 185.53$ indicates that the mean annual

rainfall has been decreasing over the time frame of study. The peak rainfall was in 2006 while the lowest rainfall was observed in 2013. The decreasing trend in rainfall may be due to climate change which is a phenomenon that has been described as a statistical variation in weather elements that persist for an extended period, typically for decades or longer. Climate change leads to a distortion of seasonal patterns and consequently, changes in rainfall patterns (IPCC, 2001).

4.2.2 Trend in Temperature Distribution (2004-2013)

From Figure 4.2, it can be observed that temperature has been fluctuating but not as much as when compared to rainfall within the time study period. The linear trend line equation $y = 0.3368x + 24.381$ indicates that mean annual temperature has been on the increase, this is also supported by the trend line as seen in Figure 4.2. Increasing trend in temperature has been associated with global warming.

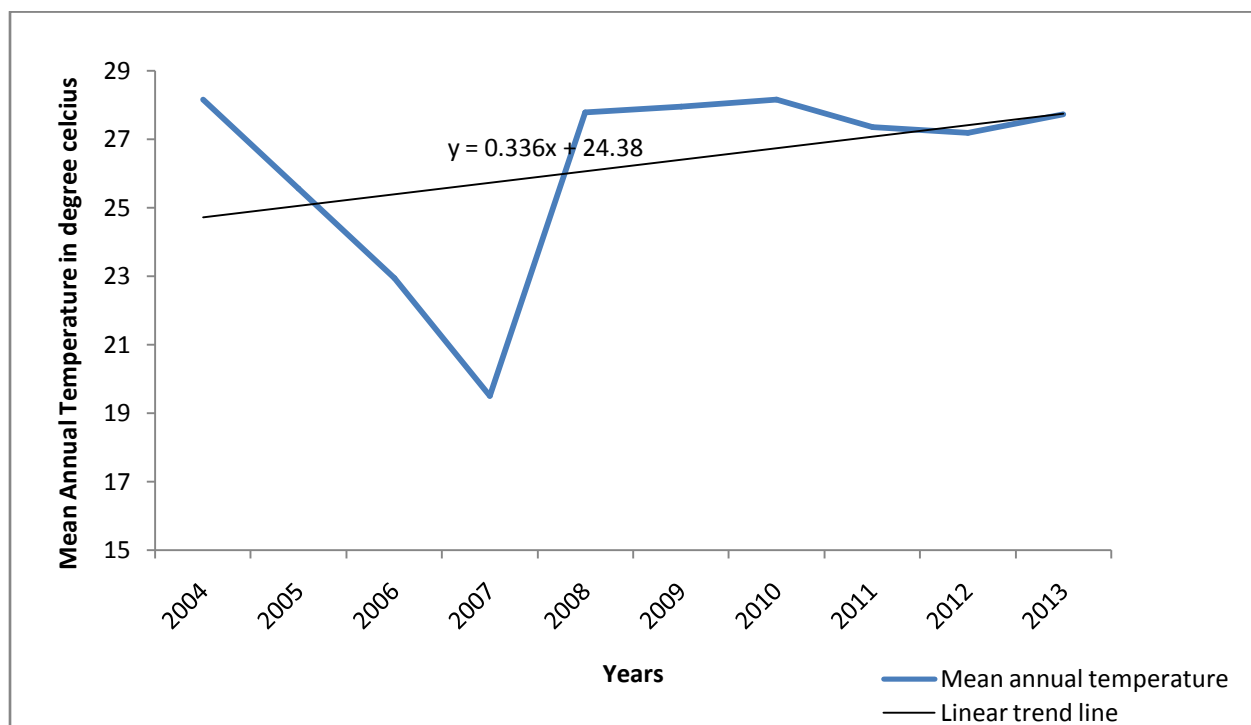


Figure 4.2: Trend of Temperature in Onitsha North Local Government Area (2004- 2013)

4.2.3 Trend in the Distribution of Relative Humidity (2004-2013)

From figure 4.3, the highest percentage of relative humidity was observed in 2006, while the lowest percentage in 2010. The trend shows that relative humidity in the study area has been fluctuating. The linear trend line equation is $y = -0.9373x + 69.469$, this indicates that relative humidity has been decreasing over the time frame of study which might be affiliated with climate change which includes shift in the frequency and magnitude of sporadic weather events .

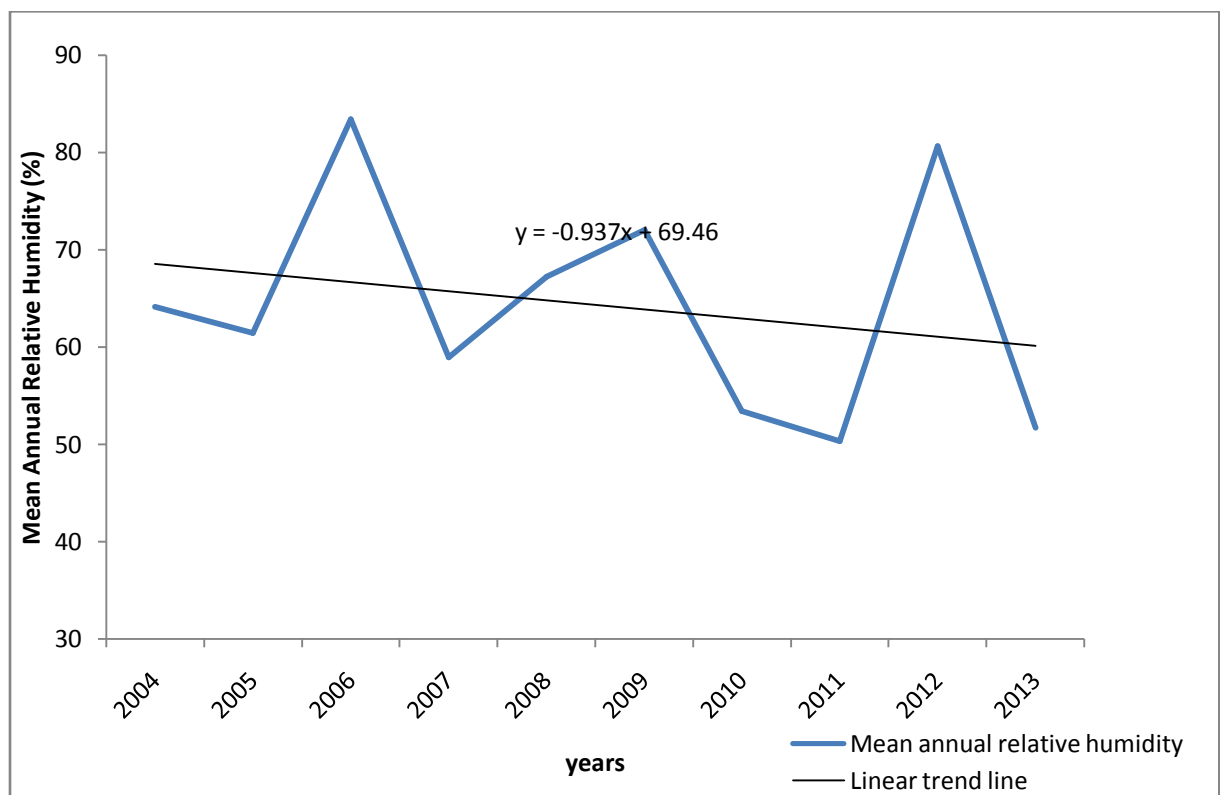


**Figure 4.3: Trend of Relative Humidity in Onitsha North Local Government Area
(2004- 2013)**

4.3 TRENDS IN THE OCCURRENCE OF THE COMMON DISEASES IN THE STUDY AREA

4.3.1 Trend in the Occurrence of Malaria (2004-2013)

For the period of 2004 to 2013, Figure 4.4 shows the trend in the occurrence of malaria.

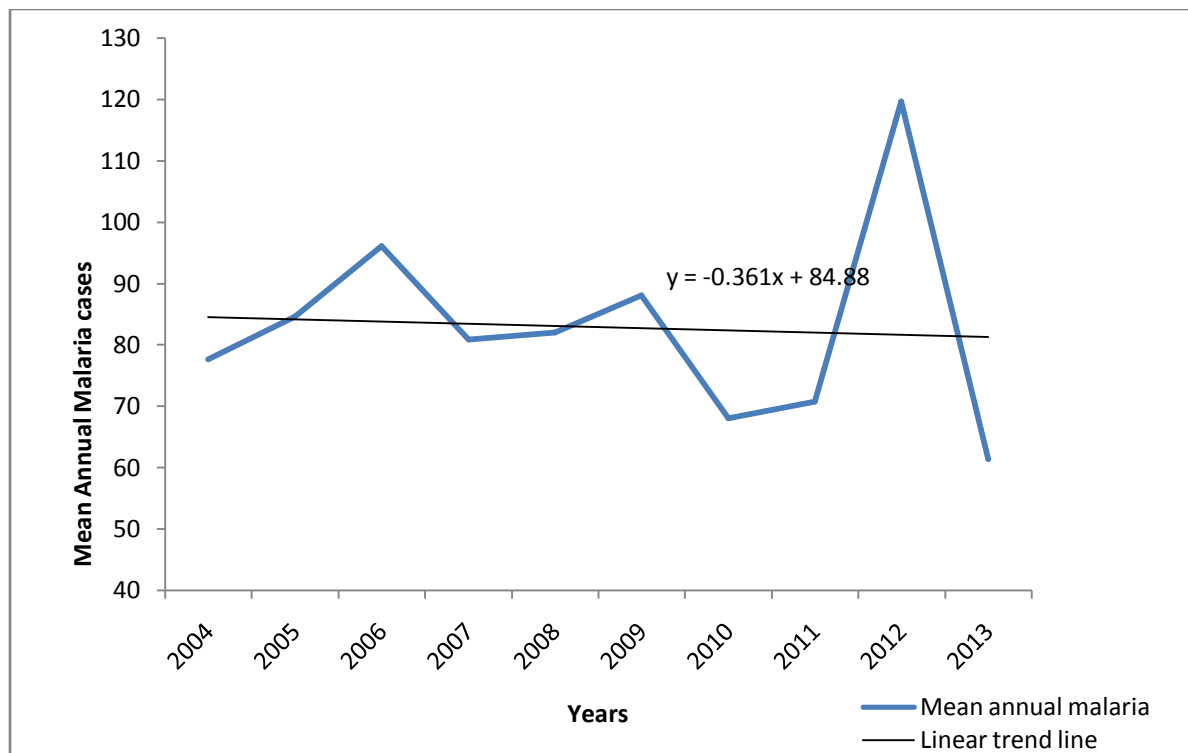


Figure 4.4 Trend in the Occurrence of Malaria in Onitsha North Local Government Area (2004-2013)

Figure 4.4 shows that the occurrence of malaria has been fluctuating with its peak occurring in 2012. This may be due to the national flood disaster of 2012. The occurrence of Malaria is generally high in the study area may be because of the high amount of rainfall received there since Malaria is associated with stagnant water which usually occurs when there is high rainfall and poor drainage systems. The trend as indicated by the linear trend line shows a slight insignificant pattern of occurrence. The linear trend line equation is $y = -0.3619x + 84.883$, indicating that the rate of occurrence of malaria has been on the decrease to a small extent which may be due to an increase in the National awareness of the use of mosquito nets over the time frame of study.

4.3.2 Trend in the Occurrence of Typhoid (2004-2013)

Trend in the occurrence of typhoid for Onitsha North Local Government Area is presented in Figure 4.5. The linear trend line equation is $y = 0.0351x + 1.9991$, indicating that the occurrence of typhoid has been increasing over the time frame of study. The trend shows that there has been a significant fluctuation in the pattern of occurrence of typhoid with its highest value in 2006 and its lowest value in 2005. The poor quality of drinking water in connection with the polluted ground water increases the chance of epidemics of water-borne diseases such as cholera and typhoid fever, and other diseases like hepatitis commonly experienced in the southern part of the country (Eze, Ikeogu, Iwuh, and Nwakama 2012). This explains the increasing trend of Typhoid in the study area.

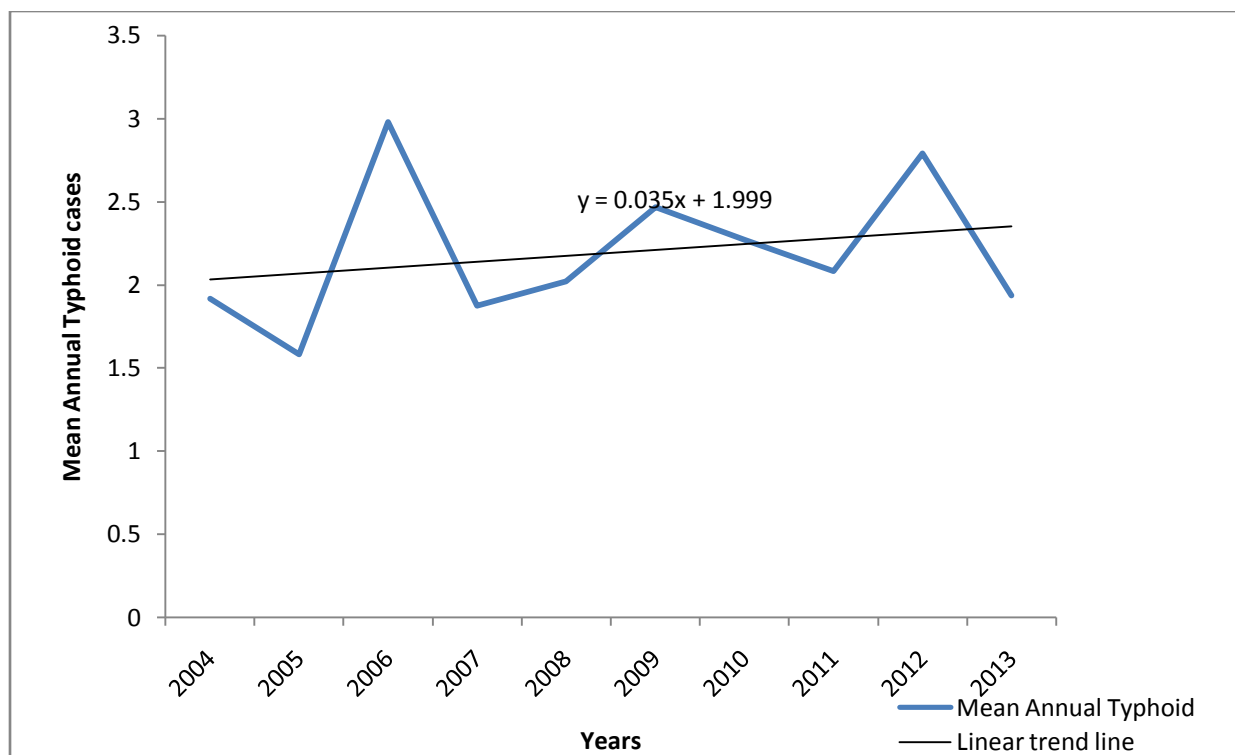


Figure 4.5: Trend in the occurrence of Typhoid fever in Onitsha North Local Government Area (2004-2013)

4.3.3 Trend in the Occurrence of Tuberculosis (2004-2013)

Figure 4.6 presents the trends in the occurrence of tuberculosis (2004-2013) in Onitsha North Local Government Area. The trend shows that the pattern of occurrence of tuberculosis in the study area has been fluctuating greatly and there is a significant increasing trend in its pattern of occurrence as shown by the trend line. The linear trend line equation $y = 0.1806x + 12.185$ also indicates that the cases of tuberculosis has been increasing over the time frame of study with its peak occurring in 2013. The increase in population density tends to contribute to the

increasing trend of Tuberculosis in Onitsha North Local Government Area since Tuberculosis is an air-borne disease.

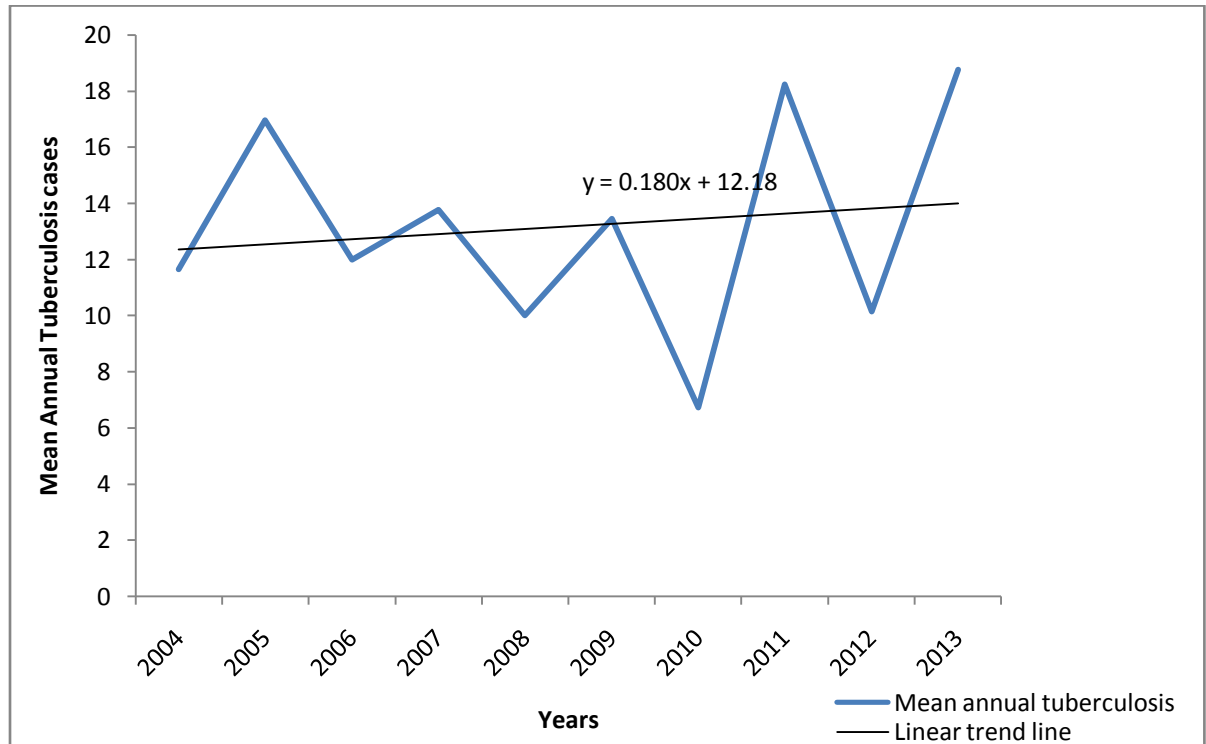


Figure 4.6: Trend in the occurrence of Tuberculosis in Onitsha North Local Government Area (2004-2013)

4.4 RELATIONSHIP BETWEEN THE VARIOUS WEATHER ELEMENTS AND THE SELECTED DISEASES

Table 4.1 shows the relationship between the weather elements and the occurrence of Malaria, Typhoid and Tuberculosis between 2004-2013 in the study area.

Table 4.1: Correlation Between the Weather Elements and Malaria, Typhoid and Tuberculosis

Weather Elements	Selected Diseases		
	Malaria	Typhoid	Tuberculosis
Rainfall	0.646 [*]	0.519	-0.341
Temperature	-0.194	-0.253	-0.102
Relative Humidity	0.852 ^{**}	0.807 ^{**}	-0.427

KEY

•	0.05 level of significance
**	0.01 level of significance

4.4.1 Relationship Between Rainfall and the Occurrence of Malaria

From Table 4.1 the correlation between rainfall and malaria was 0.646 which was significant at 0.05 level of significance. This means that there is a strong relationship between rainfall and the occurrence of malaria in the study area. Changes in rainfall are strongly and positively correlated with changes in the occurrence of malaria, i.e. an increase in rainfall would lead to an increase in the occurrence of malaria, and hence the occurrence of malaria is highly dependent on the amount of rainfall.

4.4.2 Relationship Between Temperature and the Occurrence of Malaria

The relationship between temperature and the occurrence of malaria in the study area is presented in Table 4.1. The Pearson Product Moment Correlation Co-efficient (r) between temperature and the occurrence of malaria was -0.194, hence indicating a weak negative insignificant relationship. This implies that change in temperature weakly and negatively influences changes in the occurrence of malaria.

4.4.3 Relationship Between Relative Humidity and the Occurrence of Malaria

Table 4.1 also presents the relationship between relative humidity and the occurrence of malaria in the study area. The Correlation Co-efficient (r) between relative humidity and the occurrence of malaria was 0.852 which is significant at 0.01 level of significance. This implies that there is a very strong positive relationship between relative humidity and the occurrence of malaria in the study area for the study period. The relationship indicates that a significant increase in relative humidity would likewise lead to a very significant increase in the occurrence of malaria; hence the occurrence of malaria is highly dependent on the amount of relative humidity received in the study area.

4.4.4 Relationship Between Rainfall and the Occurrence of Typhoid

From Table 4.1, the r value of the correlation between rainfall and typhoid was 0.519 which was not significant at 0.05 level of significance. This means that there is a moderate positive insignificant relationship between rainfall and the occurrence of typhoid in Onitsha North Local Government Area. An increase in rainfall would lead to a moderately insignificant increase in the cases of typhoid.

4.4.5 Relationship Between Temperature and the Occurrence of Typhoid

From Table 4.5 since the r value between temperature and typhoid was -0.253, it means that there is a weak insignificant negative relationship between temperature and the occurrence of typhoid in the study area. This means that a significant increase in temperature would lead to an insignificant decrease in the cases of typhoid, hence the occurrence of typhoid is not significantly dependent on temperature.

4.4.6 Relationship Between Relative Humidity and the Occurrence of Typhoid

The correlation between relative humidity and the occurrence of typhoid in the study area is shown in Table 4.1. The Correlation Co-efficient was 0.807 which was significant at 0.01 level of significance; indicating that there is a very strong relationship between relative humidity and the occurrence of typhoid in the study area. A significant increase in relative humidity would lead to a significant increase in the occurrence of typhoid and likewise a significant decrease in the amount of relative humidity received would lead to significant decrease in the occurrence of

typhoid, hence the occurrence of typhoid is highly dependent on the amount of relative humidity received in the study area.

4.4.7 Relationship Between Rainfall and the Occurrence of Tuberculosis

The relationship between rainfall and the occurrence of tuberculosis in Onitsha North Local Government Area is given in Table 4.1. The r value is -0.341 indicating a weak negative relationship between rainfall and the occurrence of tuberculosis in the study area. Therefore a significant increase in rainfall would lead to an insignificant decrease in the occurrence of tuberculosis and vice versa, hence the rate of occurrence of tuberculosis is not significantly dependent on the amount of rainfall received.

4.4.8 Relationship Between Temperature and the Occurrence of Tuberculosis

Table 4.1 also shows the relationship between temperature and the occurrence of tuberculosis in the study area. The correlation co-efficient value between temperature and the occurrence of tuberculosis was -0.102. This shows that the relationship between temperature and the occurrence of tuberculosis in the study area weak. A change in temperature (i.e. increase or decrease) would have a negligible effect in the opposite direction on the rate of occurrence of tuberculosis.

4.4.9 Relationship Between Relative Humidity and the Occurrence of Tuberculosis

The association between relative humidity and the occurrence of tuberculosis in the study area is shown in Table 4.1. The relationship between relative humidity and the occurrence of tuberculosis in the study area is moderate negative given that the r value is -0.427. This means

that a significant increase in relative humidity would lead to an average decrease in the occurrence of tuberculosis and likewise a significant decrease in relative humidity would lead to an average increase the occurrence of tuberculosis in the study area.

4.5 SEASONALITY OF THE DISEASES IN ONITSHA NORTH LOCAL GOVERNMENT AREA

The seasonality of malaria, typhoid and tuberculosis across the seasons for 2004-2011 is shown in Figure 4.7 to 4.17.

4.5.1 Seasonality of the Three Diseases in 2004

The seasonality of the occurrence of malaria, typhoid and tuberculosis in 2004 is shown in Figure 4.7.

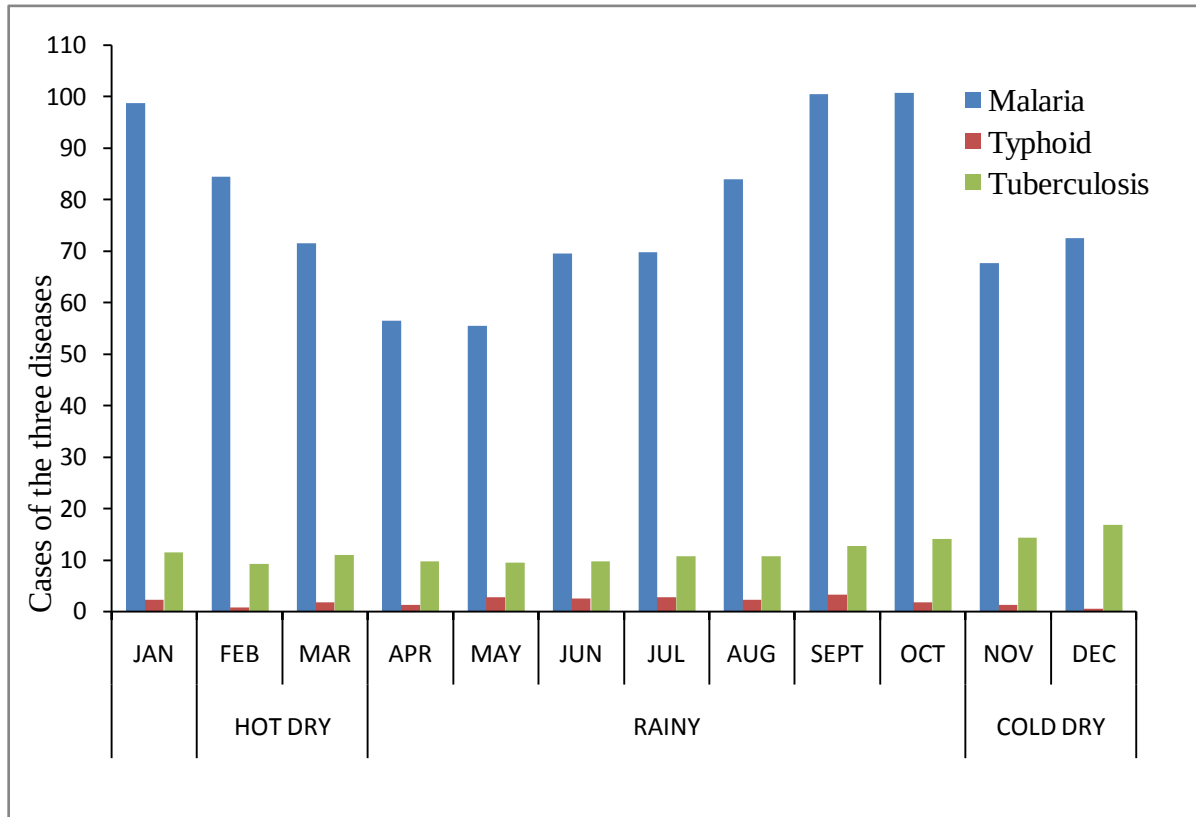


Figure 4.7: Seasonality of Malaria, Typhoid and Tuberculosis (2004)

From Figure 4.7, it can be seen that the frequency of occurrence of malaria in the study area is very high with the highest peak occurring during the rainy season peak (August to October) and its lowest incidence occurred during the early part of the rainy season (April to May). The occurrence of typhoid and tuberculosis were relatively evenly distributed throughout the year with typhoid having its peak during the mid to peak of the rainy season (June to September), while tuberculosis having its peak during the cold dry season (December).

4.5.2 Seasonality of the Three Diseases (2005)

Figure 4.8 shows the seasonality of Malaria, Typhoid and Tuberculosis in Onitsha North Local Government Area (2005).

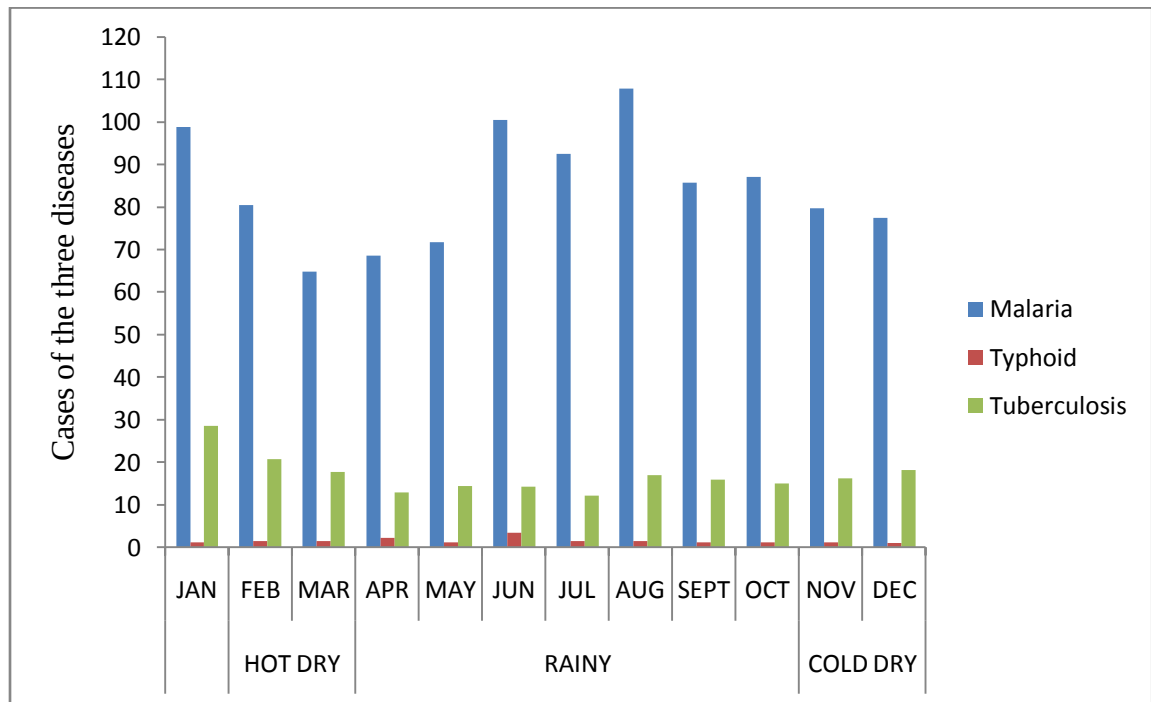


Figure 4.8: Seasonality of Malaria, Typhoid and Tuberculosis (2005)

Figure 4.8 shows that the occurrence of malaria is higher during the mid to heavy rainy season (June to October) and its lowest recorded cases occurring during the late hot to early rainy season (March to April). The high difference in its occurrence across the seasons shows that malaria is more prevalent in the rainy season. Typhoid on the other hand is also more prevalent in the rainy season peaking in June and having its lowest recorded cases in the cold dry season (November to December). In 2005, tuberculosis has its highest number of occurrence in the cold dry season (January) and its lowest incidence of occurrence recorded in the early to mid-rainy season (April to July).

4.5.3 Seasonality of the Three Diseases (2006)

The seasonality of Malaria, Typhoid and Tuberculosis for 2006 is shown in Figure 4.9.

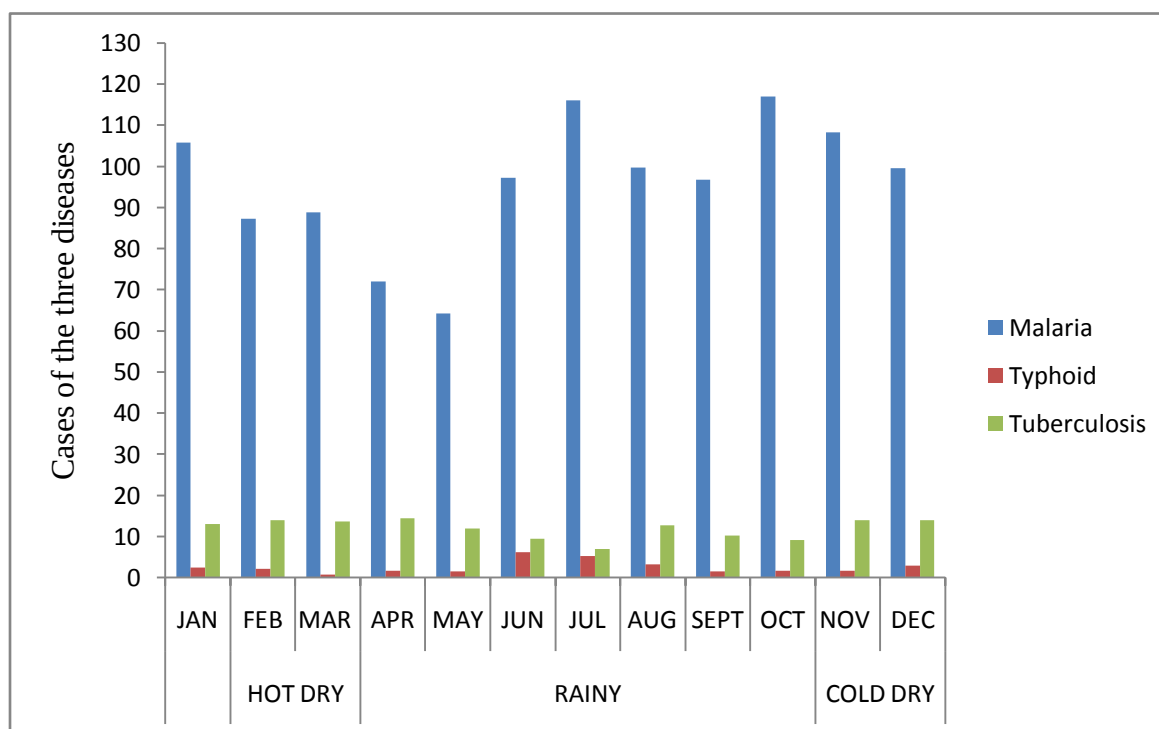


Figure 4.9: Seasonality of Malaria, Typhoid and Tuberculosis (2006)

The highest cases of malaria were recorded in the peak of the rainy season (July to October) and its lowest recorded case in the early rainy season (April to May). Typhoid also had its highest cases recorded in the rainy Season (July to August) and its lowest cases recorded in the hot dry to early rainy season (March to May). Tuberculosis had its highest reported cases in the cold dry season and its lowest reported cases occurring in the rainy season.

4.5.4 Seasonality of the Three Diseases (2007)

Figure 4.10 shows the seasonal pattern in the occurrence of Malaria, Typhoid and Tuberculosis in the study area (2007).

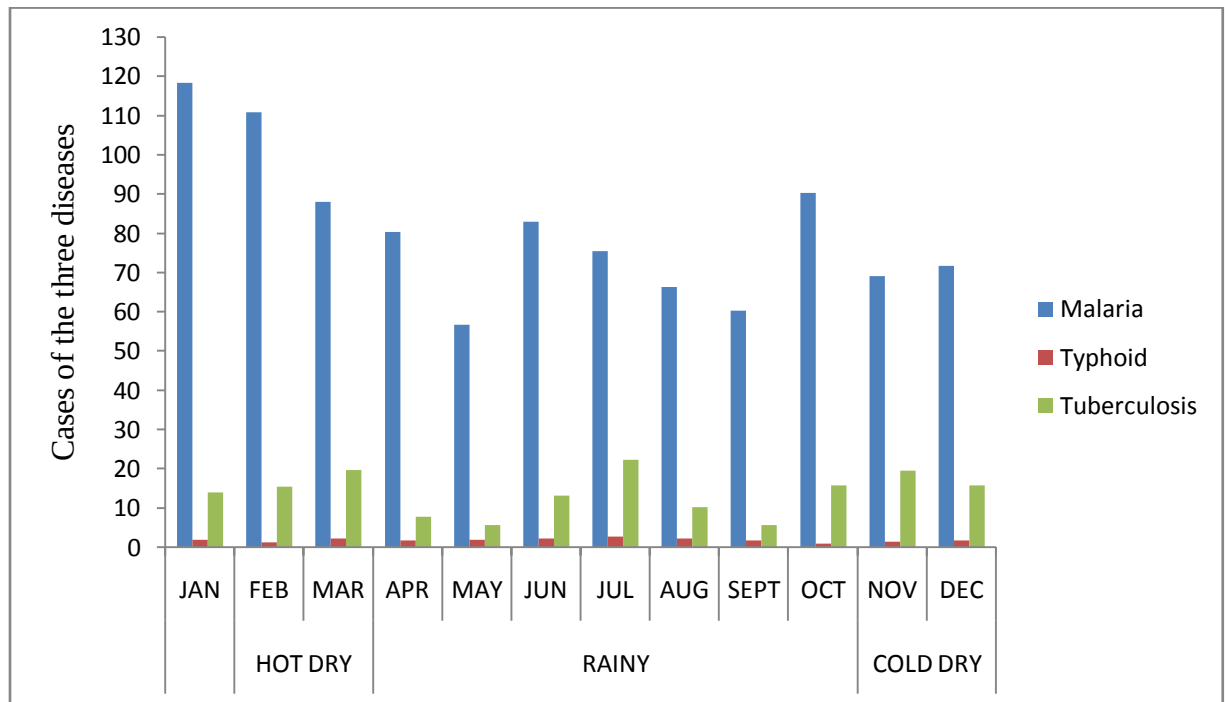


Figure 4.10: Seasonality of Malaria, Typhoid and Tuberculosis (2007)

Figure 4.10 presents the distribution of the cases of malaria, typhoid and tuberculosis for 2007. From this figure malaria had its highest occurrence in the cold dry season (January to February) and its lowest occurrence in the rainy season (April to September). This is contrary to the previous years which had their peak occurring in the rainy season. The distribution of typhoid was relatively constant throughout the year, peaking in the rainy season (May to August) and having its lowest in the cold dry season. Tuberculosis on the other hand had its highest reported case incidence in the rainy season and its lowest reported cases also occurring in the rainy season.

4.5.5 Seasonality of the Three Diseases (2008)

In 2008, Figure 4.11 showed that like in 2009 malaria also had its highest number of reported cases in the cold dry season with an average of 58.5 cases. The occurrence of typhoid was highest in cold dry season and lowest reported case also in the cold dry season. Tuberculosis had its highest cases of occurrences in cold dry and hot dry season (November to March) and its lowest number of occurrence in the rainy season.

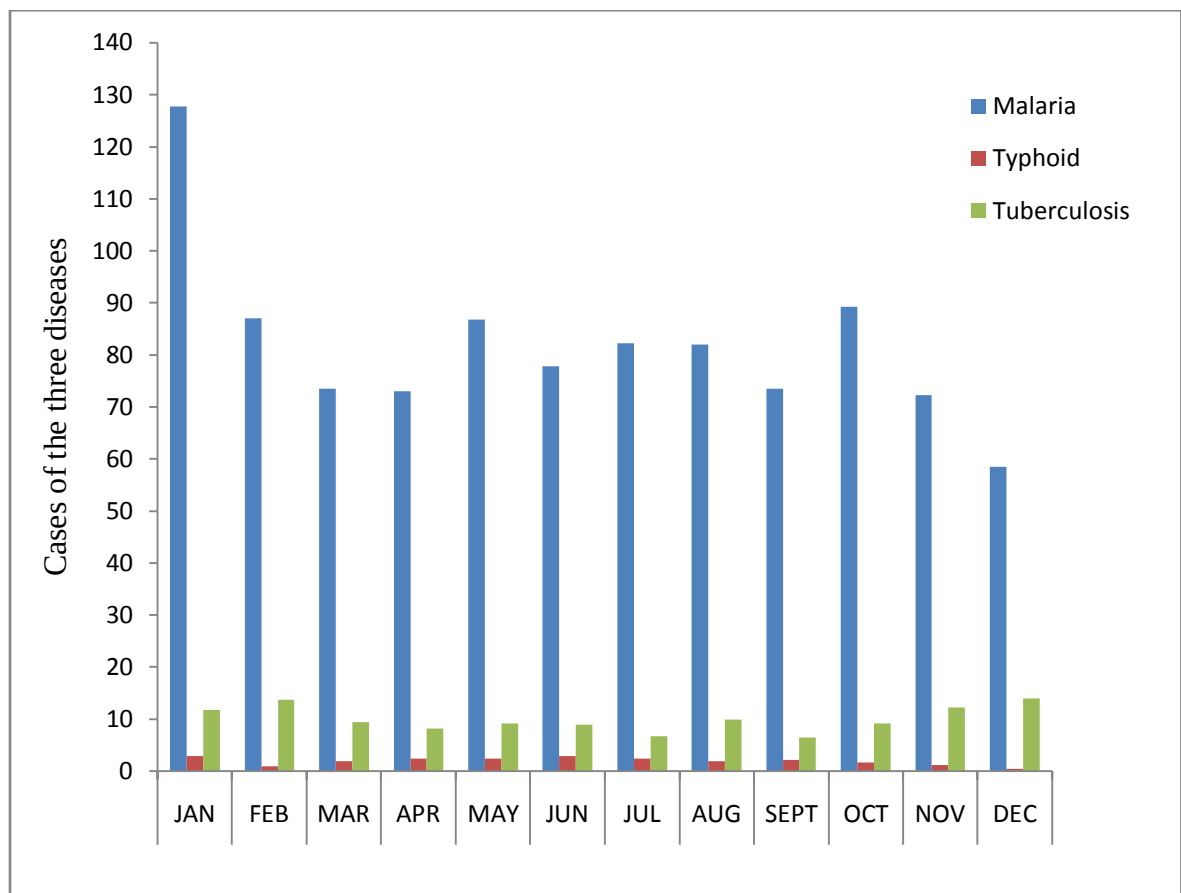


Figure 4.11: Seasonality of Malaria, Typhoid and Tuberculosis (2008)

4.5.6 Seasonality of the Three Diseases (2009)

Seasonality in the Occurrence of Malaria, Typhoid and Tuberculosis in 2009 is given

Figure 4.12.

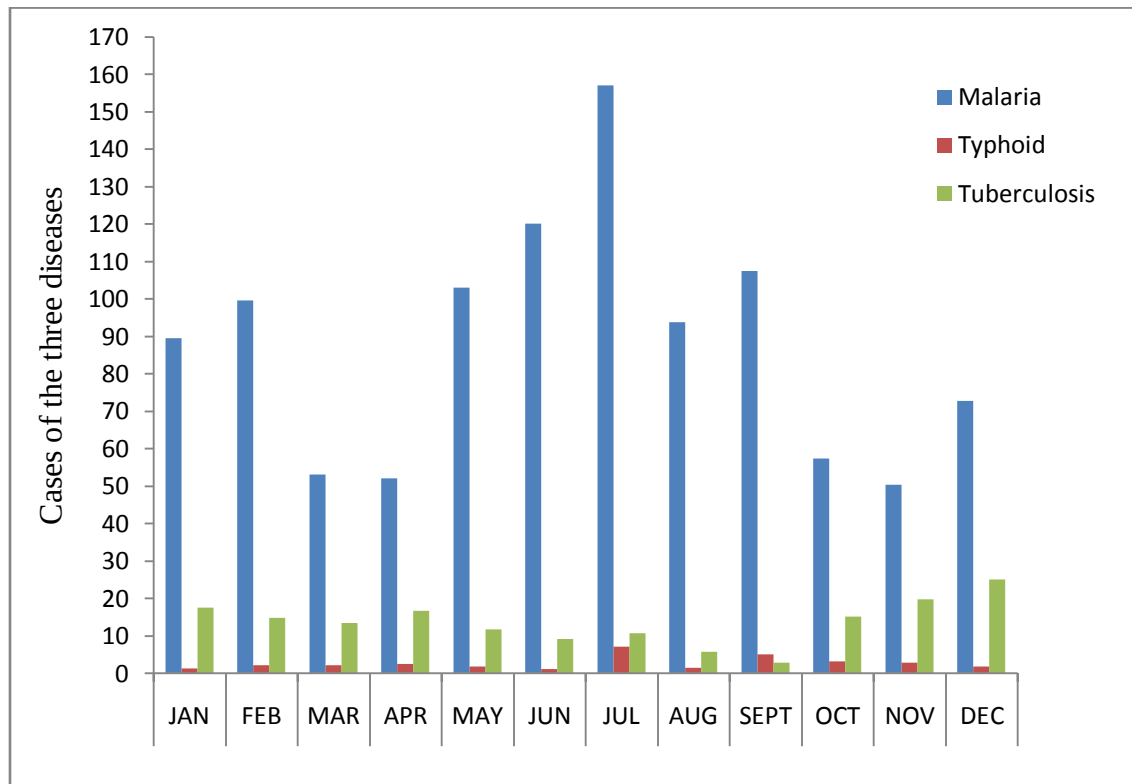


Figure 4.12: Seasonality of Malaria, Typhoid and Tuberculosis (2009)

Figure 4.12 shows that in 2011 malaria had its reported cases of highest occurrences in the rainy season when compared with the other two seasons (cold dry and hot dry) having its peak in the middle of the rainy season (May to August) and its lowest occurrences in the cold dry season (November). Typhoid on the other hand also had its highest occurrences in the peak of the rainy season (July-August) and its lowest occurring in the cold dry season (December to January). Tuberculosis was highest in the cold dry season (December –January) while the rainy season had the lowest case of tuberculosis recorded.

4.5.7 Seasonality of the Three Diseases (2010)

Figure 4.13 represents the seasonality of Malaria, Typhoid and Tuberculosis in 2010 for the study area.

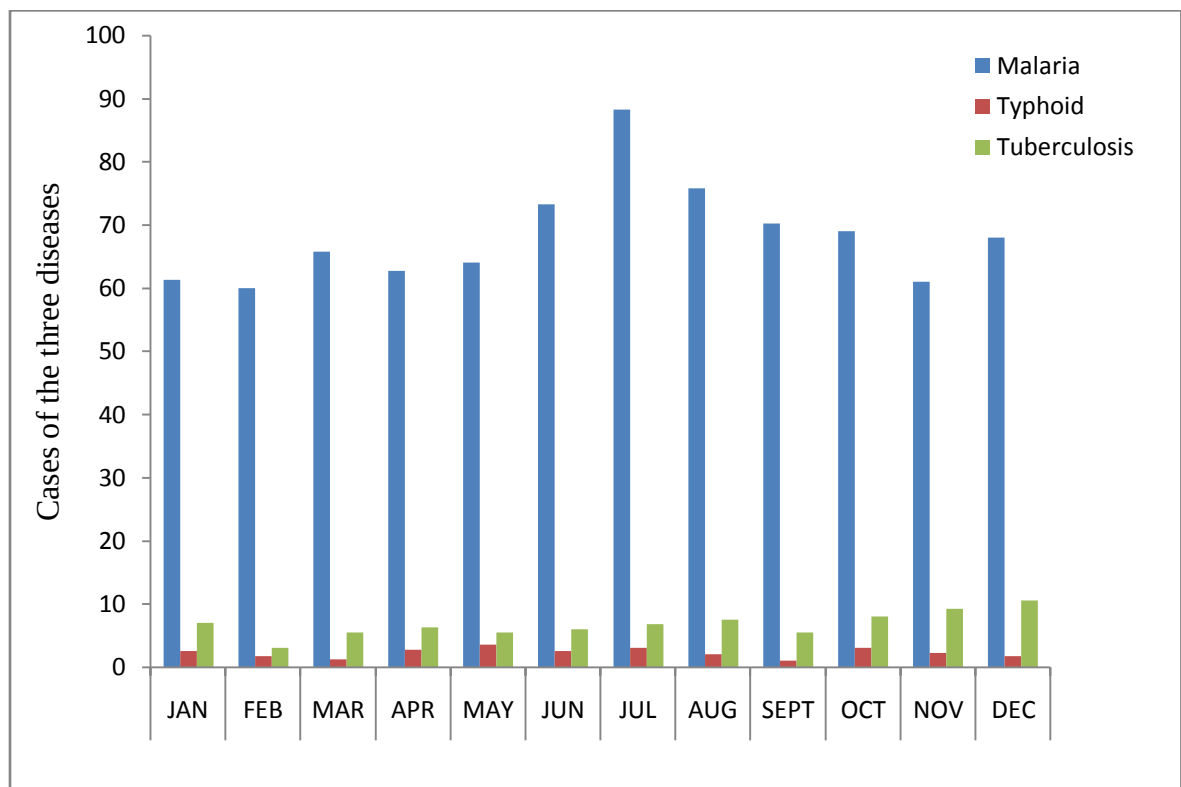


Figure 4.13: Seasonality of Malaria, Typhoid and Tuberculosis (2010)

From Figure 4.13 just like the previous year (2009), the highest reported cases of malaria was recorded in the peak of the rainy season (June -September) and the lowest reported cases was recorded at the end of the cold dry season to early hot dry season (January-February). The spread of typhoid across the months in 2010 was relatively uniform having its highest number of

occurrences recorded in the early to middle stage of the rainy season and its lowest occurrences were also recorded in the latter part of the rainy season (September). The cold dry season in 2010 produced the highest number of occurrences for tuberculosis while the lowest occurrences of tuberculosis were recorded in the hot dry season.

4.5.8 Seasonality of the Three Diseases (2011)

The seasonal distribution of Malaria, Typhoid and Tuberculosis for 2011 is shown in Figure 4.14.

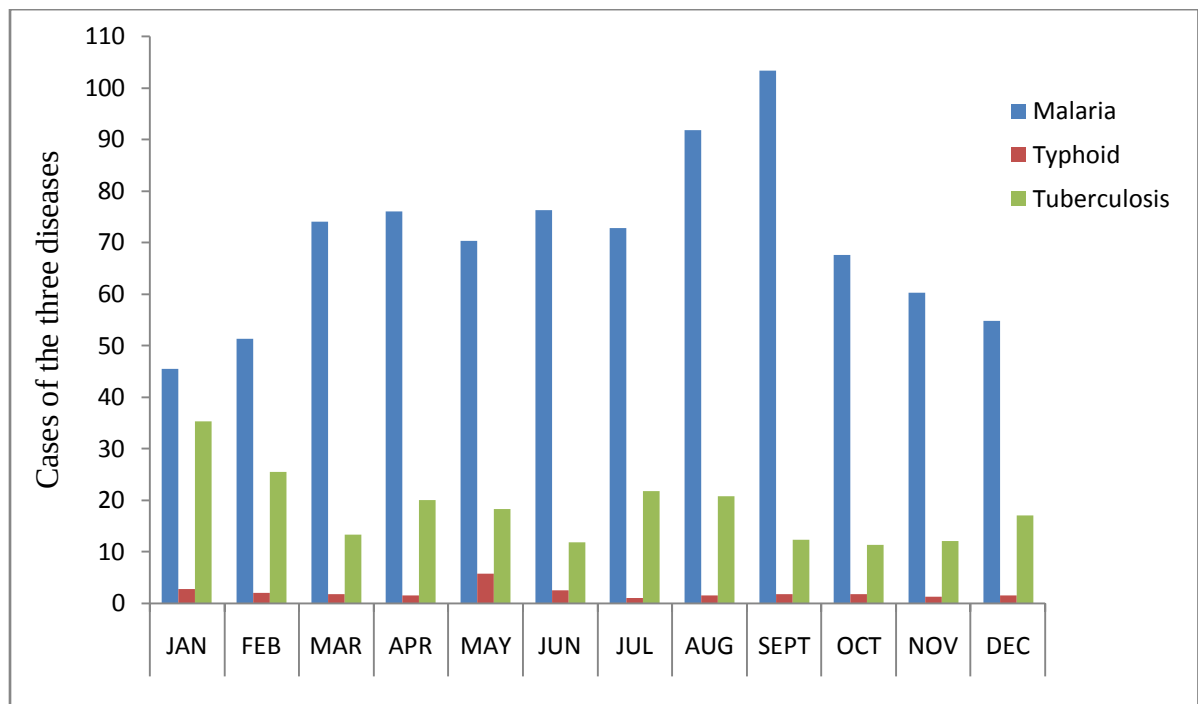


Figure 4.14: Seasonality of Malaria, Typhoid and Tuberculosis (2011)

From Figure 4.14 it is seen that the distribution of malaria is highly uneven with the highest incidence of occurrences towards the ending of the rainy season (August-September) and

its lowest incidences occurring in the cold dry to early hot season (November-February). Typhoid had its highest recorded cases at the beginning of the rainy season (May-June) and its lowest occurring at the peak of the rainy season to the cold dry season (July-December). The highest case for tuberculosis on the other hand was recorded in the cold dry season (January) while its lowest cases scenarios for 2011 was recorded in the ending part of the rainy season (September-October).

4.5.9 Seasonality of the Three Diseases (2012)

Figure 4.15 shows that the distribution of malaria was relatively high for most of the year with its peak occurring in the hot dry season (February-March) and its lowest occurring in the early part of the rainy season (April). This is different from the previous years. The occurrence of typhoid was more prevalent during the early to middle part of the rainy season (April-August) and had its lowest recorded incidence(s) in the latter part of the rainy season to most parts of the cold dry season (September-December). The highest recorded case of tuberculosis was highest during the cold dry season (January) and its lowest occurring in the rainy season.

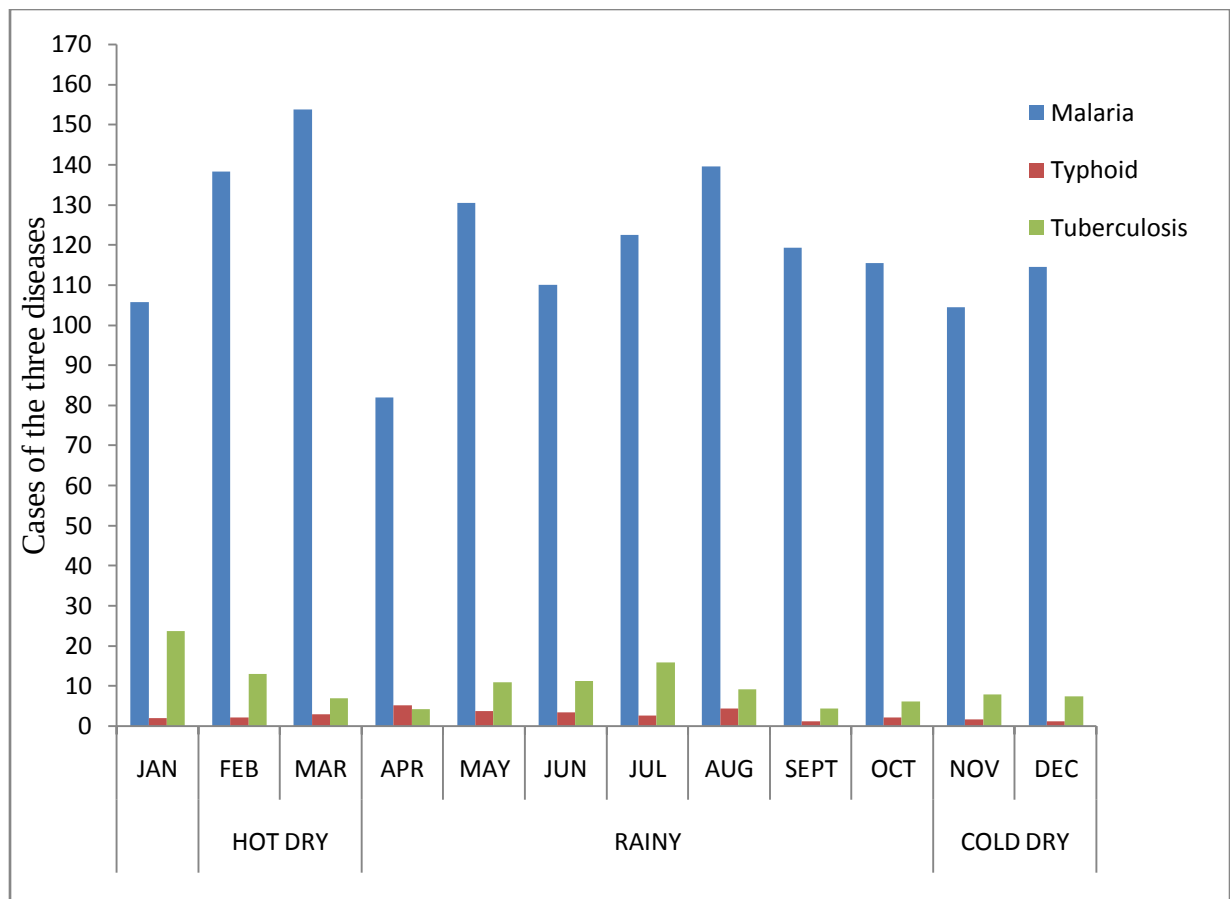


Figure 4.15: Seasonality of Malaria, Typhoid and Tuberculosis (2012)

4.5.10 Seasonality of the Three Diseases (2013)

The 2013 distribution of Malaria, Typhoid and Tuberculosis across the Seasons in 2013 is shown in Figure 4.16.

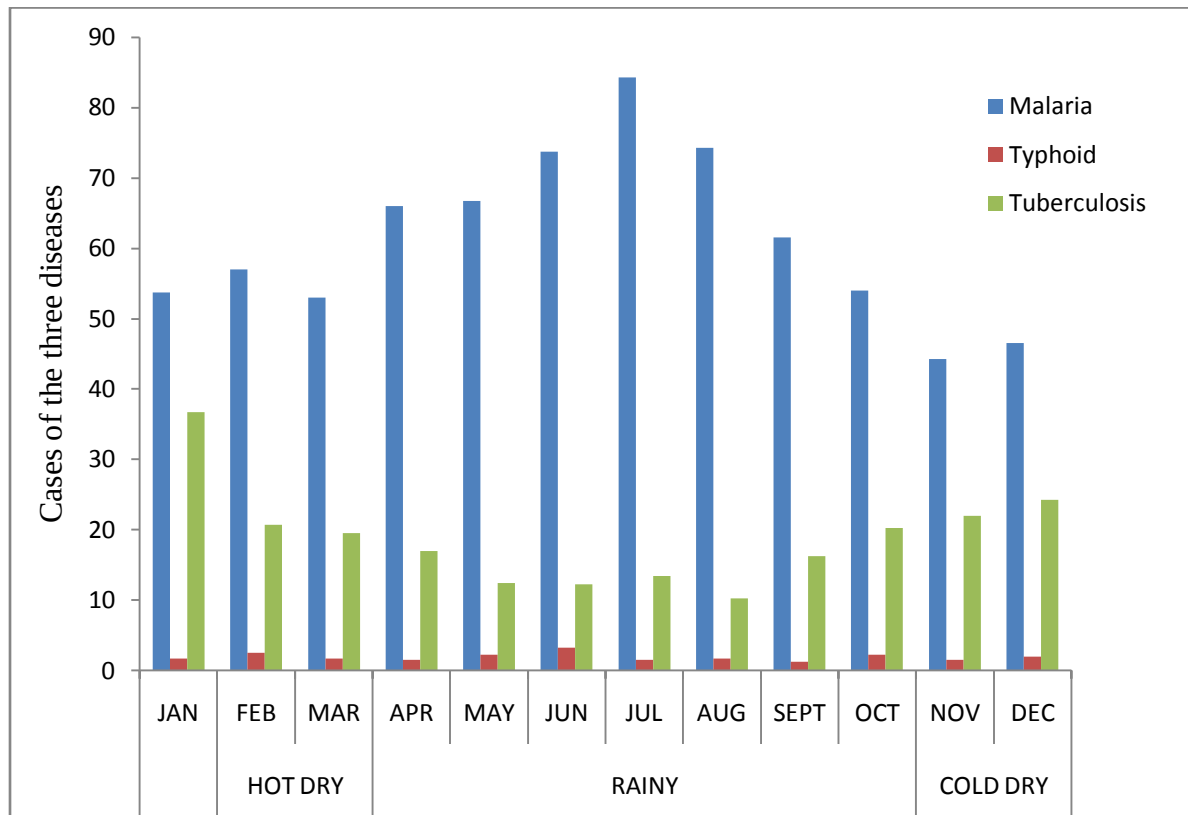


Figure 4.16: Seasonality of Malaria, Typhoid and Tuberculosis (2013)

From Fig 4.16 it can be seen that malaria is more prevalent during the rainy season having its highest occurrences in the peak of the rainy season (June-August) and its lowest cases occurring in the cold dry season (November-December). The spread of typhoid was evenly distributed throughout the year with at least 1.5 reported cases every month, though it had a notable peak in the rainy season (May-June) and a slight decline also in the rainy season

(September). The frequency of distribution for tuberculosis was highly unevenly distributed throughout the year being highly more prevalent in the cold dry season and less prevalent in the rainy season.

4.5.11 Mean Annual Seasonality of Malaria, Typhoid and Tuberculosis (2004-2013)

The mean annual seasonality of Malaria, Typhoid and Tuberculosis from 2004 to 2013 in Onitsha North Local Government Area is presented in Figure 4.17.

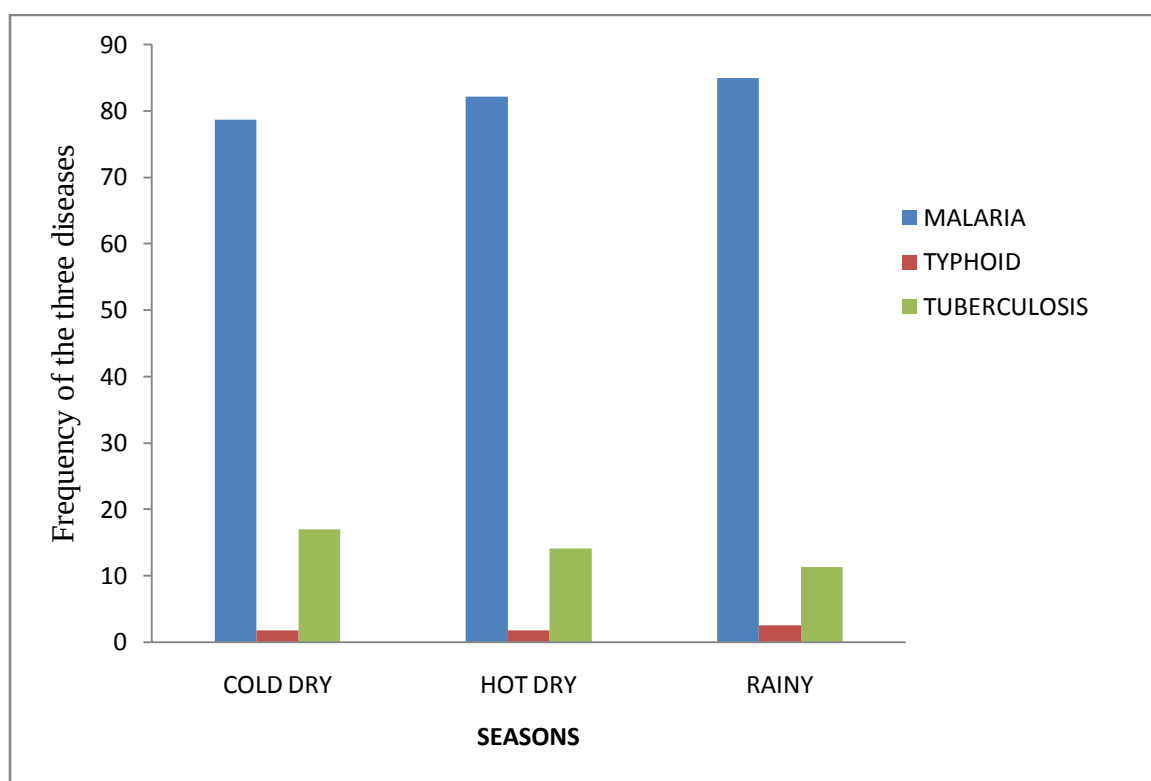


Figure 4.17: Seasonality of Malaria, Typhoid and Tuberculosis (2004-2013)

Figure 4.17 shows that between 2004 and 2013 malaria had its highest number of reported cases occurring during the rainy season with a seasonal average of 84.87 cases and had its lowest number during the cold dry season with a seasonal average of 76.62 cases. Typhoid

occurrence was relatively uniform across all seasons but was slightly higher during the rainy season. The occurrence of tuberculosis was most prevalent during the cold dry season with a reported average of 16.97, followed by the hot dry season with a reported average of 14.03 cases and lastly the rainy season with a reported average of 11.31 cases.

4.6 DISCUSSION

Fig 4.1 to 4.3 showed that rainfall, temperature, relative humidity have all been fluctuating (2004-2013). Rainfall and relative humidity exhibited decreasing trends indicating a reduction in the amount received, while temperature indicated an increasing trend which portrays that the average amount of temperature received is increasing for the time frame of study. This fluctuation has been attributed mainly to global warming which is an effect of climate change.

From Fig 4.4 to 4.6 indicated that the occurrence of malaria, typhoid and tuberculosis has been fluctuating, this may be attributed to the fluctuations also exhibited by the weather elements. The trend line showed an insignificant decrease in the occurrence of malaria and a significant increase in the occurrence of typhoid and tuberculosis. This increased amount of recorded cases of typhoid and tuberculosis may be due to an increased risk in exposure of the population to these diseases especially in terms of rapid increased population in the study area over time.

From Table 4.1, rainfall and relative humidity showed a very strong significant relationship with malaria and temperature indicated relationships which were not significant. This is supported by the statement of [Small, Hay and Goetz, \(2003\)](#) which stated that rainfall and relative humidity rather than temperature, was the primary forcing factor in malaria transmission trends in Africa during most of the twentieth century. The study area experiences high rainfall

which has a major influence in enhancing mosquito breeding and survival. An increase in rainfall may increase the presence of malaria vectors by expanding the size of the already existing larval habitat as well as creating new breeding grounds; this in turn leads to an increase in the number of malaria cases especially when preventive measures are not taken.

Relative humidity amount greatly influences the transmission of vector-borne diseases such as malaria because mosquitoes desiccate easily and as such survival decreases under dry conditions as well as increases under wetter conditions. Saturation deficit (similar to relative humidity) has been found to be one of the most critical determinants in climate/disease models. The study area experiences a relatively high amount of relative humidity all year round and this condition favours the survival of mosquitoes which increases the likelihood of malaria cases experienced. Temperature did not show any significant relationship with malaria maybe due to the fact that mosquito vectors usually undergo evolutionary responses in order to adapt to slightly increasing and reducing temperatures.

From Table 4.1 again, only relative humidity showed a very strong significant relationship with typhoid, while rainfall showed a fairly significant relationship and temperature showing a relatively insignificant relationship. This is supported by the findings of Bako(2012) which reported that there is a significant relationship between typhoid fever and relative humidity and rainfall and that the occurrence of typhoid is higher when relative humidity is higher during the rainy season. Rainfall showed a slightly significant relationship with typhoid maybe because some social factors such as economic development, living conditions etc. influences the incidence of typhoid. The presence of high relative humidity experienced in Onitsha North LGA tends to favor the prolonged and effective survival of the typhoid bacterium

called *salmonella typhi* in both food and water which are the most common mode of typhoid transmission.

Furthermore from Table 4.1, none of the weather elements had a strong significant relationship with tuberculosis. This may be due to lag periods of months between the time of infection of tuberculosis and the time of clinical manifestation(Fares, 2011), which is greatly affected by the different level of immune systems of the infected persons. Tuberculosis transmission may be greatly influenced indirectly by different social or behavioural patterns.

From Figures 4.7 to 4.16, the highest occurrence of malaria cases was recorded in 2012 during the hot dry season with an average amount of 146 reported cases, while the lowest amount was recorded in 2013 during the cold dry season with an average amount of 48.12. It was observed that 2012 in general had the highest number of cases and 2013 had the lowest malaria cases recorded during the time frame of study. In Figure 4.17, malaria occurred most during the rainy season, this may be because female anopheles mosquitos lay their eggs in stagnant water which is abundant during the rainy season. This goes in agreement with the findings of Akinbola and Omotosho(2004) and Bako (2012).

Figure 4.7 to 4.16 showed that the highest cases of typhoid cases was recorded in 2012 during the rainy season with an average amount of 3.32 recorded cases, while the lowest amount was recorded in 2005 during the cold dry season with an average amount of 1.17 during the time frame of study. Figure 4.17 showed that typhoid occurred most during the rainy season due to the presence of polluted ground water and poor sanitation which increases during the rainy season.

Rainfall helps in influencing the transportation and dissemination of the infectious agents that causes typhoid. This finding is also supported by the findings of Bako(2012).

The highest amount of tuberculosis occurrence was recorded in 2013 during the cold dry season with an average amount of 27.67, while the lowest was recorded in 2010 during the hot dry season with an average amount of 4.25 within the time frame of study as seen in Figure 4.7 to 4.16. Tuberculosis occurred most during the cold dry season as seen in Figure 4.17, this is supported by the findings of Nakaji *et al.*,(2004) and contrary to the findings of Fares (2011). The increased occurrence of tuberculosis in the cold dry season may be because tuberculosis is an air borne disease which may be spread more when the environment is dry and windy; this condition helps in the transportation of mycobacterium especially since tuberculosis spreads more through the inhalation of droplets from the cough or sneeze of infected persons.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

This research aimed at analyzing the relationship between some weather elements and the occurrence of some diseases in Onitsha North Local Government Area, Anambra State. This was carried out using weather records of rainfall, temperature and relative humidity for 10 years

(2004-2013), which was collected from NIMET Anambra State office, Awka. The records of cases of Malaria, Typhoid and Tuberculosis were collected from St Charles Borromeo Hospital, Onitsha General Hospital, Iyi Enu Missionary Hospital, St Patricks Hospital and Maternity all in Onitsha town over the same period. The research set for itself the tasks of analysing the trends of the weather elements and selected diseases, the relationship between the weather elements and the diseases, as well as also looking at the seasonal distribution of these diseases.

Time series analysis was used to determine the trend in the occurrence of the weather elements and selected diseases. Pearson Product Correlation Coefficient Moment was used to test the relationship between the variables. The following results were observed; Rainfall and Relative Humidity showed decreasing trends with linear trend line equations of $y = -5.7539x + 185.53$ and $y = -0.9373x + 69.469$ respectively, while temperature showed increasing trend with a linear trend line equation of $y = 0.3368x + 24.381$. Malaria had a trend line equation of $y = -0.3619x + 84.883$ which showed a slight decreasing trend while typhoid and Tuberculosis showed increasing trends with trend line equations of $y = 0.0351x + 1.9991$ and $y = 0.1807x + 12.183$ respectively. The result of the research also indicated that these diseases are influenced differently by the different weather elements; Rainfall showed a significant relationship with Malaria with an r value of 0.646 and an insignificant relationship with Typhoid and Tuberculosis having r values of 0.519 and -0.341 respectively, while there was no significant relationship with temperature and any of the diseases with malaria having an r value of -0.194, typhoid; -0.253 and tuberculosis; -0.102. Relative Humidity on the other had showed a significant relationship with Malaria with an r value of 0.852 and also with Typhoid having an r value of 0.807 and an insignificant relationship with Tuberculosis with r value of -0.427.

Seasonal analysis revealed that the cold drier months had the least number of recorded cases of malaria and typhoid with an average of 76.62 and 1.75 cases respectively but had the highest number of recorded cases for tuberculosis with 16.97 cases, while the rainy season had the highest number of recorded cases for both malaria and typhoid with 84.87 and 2.46 cases respectively. This may be attributed to the presence of water which enhances the growth and proliferation of some disease pathogens. Most cases of Tuberculosis were reported in the cold dry season while the least cases were reported in the rainy season. Based on the researcher (personal observation), most of the houses are clustered together which causes overcrowding and increases the frequency of person to person contact, this however makes the place more conducive for the multiplication and spread of diseases like tuberculosis.

Based on these outcomes, the null hypothesis which stated that there is no significant relationship between rainfall, temperature and relative humidity and the occurrence of Malaria, Typhoid and Tuberculosis was accepted for temperature and rejected for rainfall and relative humidity in the case Malaria, accepted for rainfall and temperature and rejected for relative humidity in the case of Typhoid and was accepted for all the elements in the case of Tuberculosis in the study area. This implies that different diseases are influenced differently by the different weather elements with some of the weather elements having a significant effect and others having an insignificant effect.

5.2CONCLUSION

The research investigated the effect of temperature, rainfall and relative humidity on the occurrence of malaria, typhoid and tuberculosis in Onitsha North LGA. This research shows that

malaria and tuberculosis were the two most common diseases that occur in the study area. The relationship between malaria, typhoid and the weather elements was high while that of tuberculosis was relatively moderate with relative humidity having the most significant effect on the diseases. On the seasonal basis, all the three climatic elements were found to influence the occurrence of these diseases based on prevailing season, but the influence varied from one disease to another. It was observed that malaria and tuberculosis had the highest number of mean of occurrence in all the months. The frequency of typhoid was low when compared to malaria and tuberculosis. The study showed that relative humidity and rainfall have a greater influence on the occurrence of malaria and typhoid when compared to the effect of temperature, hence malaria and typhoid showed a more significant relationship with the weather elements.

In conclusion, weather has profound effect on the rate of occurrence for malaria, typhoid and tuberculosis in Onitsha North LGA, the level of the effect varied from one disease to another for most of the study period. The recorded cases was higher in certain particular seasons but differed on one or two occasions being that the spread of diseases is not merely affected by weather elements alone but may also be affected and induced by other environmental factors such as overcrowding, poor sanitation etc.

5.3 RECOMMENDATIONS

1. The state government should come up with programmes that involve developing innovative approaches to analyze weather and climate in the context of human health in order to design a seasonal pro-active mitigation which would be based on vector

control. This may also enable the reliable projection of the vulnerability of the population to diseases.

2. Because of the prevalence of malaria in the study area, it is recommended that free mosquito nets should be provided regularly to the people.
3. Enlightenment programmes should be conducted to educate the people on the effect of climate change on the occurrence of diseases.
4. Proper town planning should be carried out by the State government in order to reduce the rate of indiscriminate building of houses so as to prevent the congestion of buildings.
5. The State government should provide safe and adequate drinking water for the masses to reduce the incidences of waterborne diseases.
6. Anambra State government should encourage proper environmental sanitation so as to clean the environment and reduce stagnant water which promotes the breeding of mosquitoes.

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