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Impact of Climate Change on the Outbreak of Infectious Diseases Among Children in Bangladesh: It's Prevention and Control

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IMPACT OF CLIMATE CHANGE ON THE OUTBREAK OF INFECTIOUS DISEASES AMONG CHILDREN IN BANGLADESH: IT'S PREVENTION AND CONTROL

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IN

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By

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INSTITUTE OF ENVIRONMENTAL SCIENCE

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IMPACT OF CLIMATE CHANGE ON THE OUTBREAK OF INFECTIOUS DISEASES AMONG CHILDREN IN BANGLADESH: IT'S PREVENTION AND CONTROL

Ph.D Dissertation

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DECLARATION

I do hereby declare that the thesis entitled "**IMPACT OF CLIMATE CHANGE ON THE OUTBREAK OF INFECTIOUS DISEASE AMONG CHILDREN IN BANGLADESH: IT'S PREVENTION AND CONTROL**" submitted to the Institute of Environmental Science, University of Rajshahi for the award of Doctor of Philosophy in Environmental Science is the results of my own experimental research work under the supervision of Professor Dr. Md. Sarwar Jahan (Principal supervisor) and Dr. Md. Redwanur Rajman, Associate Professor (Co-supervisor), Institute of Environmental Science, Dr. Md Jawadul Haque, Professor and Head, Community Medicine (Co-supervisor), Rajshahi Medical College, University of Rajshahi, Bangladesh.

I further declare that this thesis or any part of it has not been submitted to any other University for any degree or diploma. To the best of my knowledge and belief the contents or part thereof the thesis was not published previously by anyone except due reference is made in the text whenever needed.

Zaman.

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DEDICATED

To my Respected Parents

Alhaj Md. Abdur Razzaque

Anwara Begum

My Beloved Wife

Dr Manzuara Khatun

And

My Affectionate Sons

A K M Rakinuzzaman

A K M Rayatuzzaman

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CERTIFICATE

This is to certify that the thesis entitled "**IMPACT OF CLIMATE CHANGE ON THE OUTBREAK OF INFECTIOUS DISEASE AMONG CHILDREN IN BANGLADESH: IT'S PREVENTION AND CONTROL**" submitted for the degree of Doctor of Philosophy is an original research work by A K M Kamruzzaman, carried out at the Institute of Environmental Science, University of Rajshahi, under our joint supervision. The thesis or part thereof has not been previously presented for any diploma or degree to any other University.

It is also noted that the researcher has made some distinct contribution through this original study in the field of climate change and public health. We gladly recommend him to submit the thesis to the University for the award of Ph.D degree.

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A K M Kamruzzaman

Acronyms and Abbreviation

ADB	: Asian Development Bank
ARI	: Acute Respiratory Illness
BBS	: Bangladesh Bureau of Statistics
BCAS	: Bangladesh Center for Advanced Studies
BMD	: Bangladesh Meteorological Department
CCC	: Climate Change Cell
CDMP	: Comprehensive Disaster Management Programme
CES	: Coverage Evaluation Survey
DGHS	: Director General of Health Service
FGD	: Focus Group Discussion
GoB	: Government of Bangladesh
GFDL	: Geophysical Fluid Dynamics Laboratory
IgM	: Immunoglobulin 'M'
IPCC	: Intergovernmental Panel on Climate Change
LGED	: Local Government and Rural Development
MDGs	: Millennium Development Goals
MIS	: Management Information System
MOEF	: Ministry of Environment and Forest
NGO	: Non-Government Organization
OPV	: Oral Polio Vaccine
PPS	: Probability Proportional to Size
SEARO	: South East Asia Regional Office
UHC	: Upazila Health Complex
UNFCC	: United Nation Framework convention on Climate Change
UNEP	: United Nations Environmental Programme
VBZD	: Vector Borne Zoonotic Disease
WB	: World Bank
WHO	: World Health Organization
WMO	: World Meteorological Organization

Abstract

The impact of climate change and global warming are worldwide and global concern. Climate change related events like temperature, rainfall, humidity, cyclone etc. have direct and indirect adverse impacts on the outbreak of infectious disease among children. WHO demonstrates in a report estimates that more than 33% of diseases in children under the age of 5 are caused by environmental exposures. Infectious diseases continue to be the major cause of morbidity and mortality worldwide. Bangladesh is unfortunately home to many infectious diseases. In the recent national demographic and health survey (year 2011) 62% of deaths among children under the age of 5 years in Bangladesh were ascribed to infectious diseases. A number of water, air and vector borne infectious diseases including diarrhoea, typhoid, measles, rubella, kala-azar, malaria and dengue etc. are common in Bangladesh. Emerging Nipah virus and chikungunya are also prevailing in many areas of the country.

This study was conducted to determine the "Impact of climate change on the outbreak of infectious diseases among children in Bangladesh: its prevention and control" in two climate sensitive district of the country. The study area Rajshahi and Naogaon are the western districts known as barindh area in Bangladesh and poses drought prone plane land, riverine and low lands.

The long-term changes of annual mean, maximum and minimum temperature of study area over the study period (1964-2011) found to have in general increasing trends in annual mean and annual mean minimum temperature but the mean maximum temperature slightly rising in recent past decades. Seasonal mean temperatures are also found to have increased trend. The observed highest average maximum temperature was 30.55^0C in the month

of April in pro monsoon season and the lowest average temperature was 15.45^{0}C in the month of January in winter season. The long-term changes in annual rainfall showed declining trend. The average annual rainfall was 1489 mm/year. Seasonal rainfalls also showed markedly reduced in winter and post autumn season. Most of the rainfalls occurred in monsoon season that is also declined in the study area.

The study indicates that the climatic variables including temperature and rainfall (seasonal and annual) are factors for infectious disease outbreak like diarrhea, kala-azar, measles etc. in the study area. Incidence of diarrhoea showed positive correlation with both annual and seasonal rainfall and temperature implies that diarrhoea is endemic in the study area. Kala-azar was also found to be positively correlated with rainfall and annual maximum temperature but found negative with annual minimum temperature.

The primary data reveals that temperature is the main and rainfalls comes next as causes for diarrhea, kala-azar, measles like disease and newer Nipah virus infection and their outbreak among children. Data showed that the children in the study area were highly vaccinated. Among the vaccine preventable diseases only measles like cases and outbreak found. In addition to laboratory confirmed measles outbreak a large number of measles like outbreak identified as laboratory confirm rubella outbreak which is newer in the study area. The incidence of measles like disease was found positive correlation with maximum temperature and negatively correlated with average minimum temperature and total annual rainfalls.

To address the existing and future impact of climate change on the outbreak of infectious diseases among children, climate sensitive infectious disease surveillance, strengthening of routine immunization and introduction of new vaccination program need to be considered immediately.

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Chapter One
Introduction

Climate is a determinant of health. The long term good health of population depends on the continued stability and functioning of the biosphere's ecological and physical system. Climate and weather are important components of complex ecosystems, and with these changes, the dynamic balance between the living components of ecosystems are often disturbed. Ecosystem instability can result in changes in pathogen prevalence, altered pathogen transmission profiles, and increased host susceptibility. These instabilities can have dramatic affects on the health. Climate constrains the range of infectious diseases, whereas weather affects the timing and intensity of outbreaks. A long-term warming trend is encouraging the geographic expansion of several important infections, whereas extreme weather events are spawning "clusters" of disease outbreaks and a series of surprises. Ecological changes and economic inequities strongly influence disease patterns. However, a warming and unstable climate is playing an ever increasing role in driving the global emergence, resurgence, and redistribution of infectious diseases (Paul, 2004). All infections involve an agent (or pathogen), host(s), and the environment. Some pathogens are carried by vectors or require intermediate hosts to complete their life cycle. Climate can influence pathogens, vectors, host defenses, and habitat.

Bangladesh is highly vulnerable to natural disasters due to the frequency of extreme climate events and its high population density. Higher temperatures including more extreme weather events and sea level rise are already evident in Bangladesh. Temperature trends for the daily maximum series and the daily minimum series of the annual and seasonal basis have shown that the overall temperature regime in Bangladesh is showing a rising trend (IPCC 2007). One estimate is that the average increase in temperature in Bangladesh would be 1.3°C and 2.6°C by the year 2030 and 2075 respectively with respect to the base year 1990 (IPCC, 2007). Global warming will increase the intensity of southwest monsoon, which will, in turn, increase the water and food borne diseases (Earn *et. al.*, 2000). Incidence of vector-borne diseases like malaria, leishmania and dengue are likely to increase as a result of climate change in this region. Increase in temperature may provide better environment for breeding of mosquito and sand fly in places where the temperature were previously below optimum (Lindsay *et al.*, 1996).

World Health Organization (WHO) in a report demonstrates that more than 33% of diseases in children under the age of 5 are caused by environmental exposures. Preventing environmental risk could save as many as four million lives a year in children alone, mostly in developing countries.

Infectious diseases continue to be the major cause of morbidity and mortality worldwide. Bangladesh is unfortunately home to many infectious diseases. Over the last several decades Bangladesh has made remarkable progress in reducing the human health burden of infectious disease, especially in children, largely due to reduction in mortality from infectious diseases. Despite substantial progress, vaccine preventable diseases remain as important causes of ill health and premature death in Bangladesh. In the most recent national demographic and health survey (year 2011) 62% of deaths among children under the age of 5 years in Bangladesh were ascribed to infectious diseases. This accounts for 55 deaths per 1000 live births. To achieve MDGs then childhood infectious disease mortality needs to be reduced by 34 deaths per 1000 live births, or a 38% reduction between 2000 and 2015. Childhood and adult mortality due to vaccine preventable infectious diseases can be reduced dramatically through improved management of infectious diseases and prevention via introduction of vaccines and behavior modification. The use of vaccines results in a profound alteration of the environment in which parasites live. Indeed, the goal of vaccination is to protect individual hosts and consequently decrease parasite prevalence. Ultimately, this may even lead to the eradication of the disease (Fine *et al.*, 1982). These epidemiological consequences of vaccination have received a considerable amount of attention, both from an empirical and a theoretical standpoint (Anderson & May 1991; McLean & Blower 1995; Earn *et al.*, 2000; Rohani *et al.*, 2000; Tildesley *et al.*, 2006). Immunization describes the whole process of delivery of a vaccine and the immunity it generates in an individual and population. Government of Bangladesh has adopted a number of national policies with a view to provide basic health services to all with special emphasis on children and woman to ensure that they would enjoy their rights. The future of the nation lies on the head of the children of today. The future will be bright and prosperous if we provide the opportunities and allow the children to develop their potentials.

The World Health Organization reports that since 1976, more than 30 diseases have appeared that are new to medicine, of equal concern is the resurgence and redistribution of old diseases. There were some researches and studies on climate change and its impacts in Bangladesh at different times by both government and non-government organization and institutions. But research on human health impacts due to climate change in Bangladesh has not gained much focus before 2006. There is very little information about climate change and infectious disease burden in Bangladesh. On 3rd of December 2009 Ministry of Health and Family Welfare of Bangladesh announced to open a new climate change cell to look into the climate-induced disease burden in the country.

1.1 The Climate System

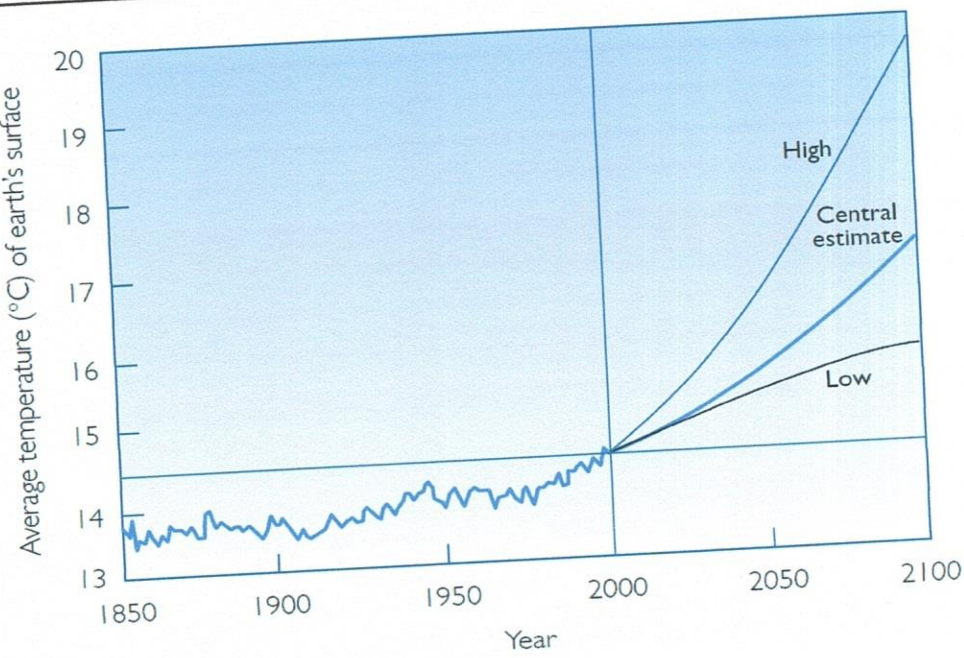
Our planet's climate is always changing. In the past it has altered following natural causes but at the present the changes have accelerated as a result of human behavior. During the Earths history, the climate has changed many times and has included ice ages and period of warmth. Before the Industrial Revolution, natural factors such as volcanic eruptions, changes in the Earth's orbit, and the amount of energy released from the sun were the primary factors affecting the Earth's climate. On a global scale, climate is largely regulated by how much energy the Earth receives from the sun and how much energy it releases back to space. Earth's climate is determined by complex interactions between the Sun, oceans, atmosphere, cryosphere, land surface and biosphere. The Sun is the principal driving force for weather and climate. Five concentric layers of atmosphere surround this planet. The lowest layer (troposphere) extends from ground level to around 10-12 km altitude on average. The weather that affects Earth's surface develops within the troposphere. The next major layer (stratosphere) extends to about 50 km above the surface. The ozone within the stratosphere absorbs most of the sun's higher energy ultraviolet rays. Above the stratosphere there are three more layers: mesosphere, thermosphere and exosphere. Overall, these five layers of the atmosphere approximately halve the amount of incoming solar radiation that reaches Earth's surface. In particular, certain "greenhouse" gases, present at trace concentrations in the troposphere absorb about 17% of the solar energy passing through it. Of the solar energy that reaches Earth's surface, much is absorbed and reradiated as long-wave (infrared) radiation. Some of this outgoing infrared radiation is absorbed by greenhouse gases in the lower atmosphere, which causes further warming of Earth's surface. The greenhouse gases radiate this energy in all directions, including back to the Earth again. This energy is used in a number of processes, including heating the ground surface, melting ice and snow, evaporating water, and plant photosynthesis. Most importantly this energy remains trapped within the climate system, warming the Earth's surface to an average of 14°C. This phenomenon, called the "natural greenhouse effect," keeps the Earth in a temperature range that allows life to thrive. Without it, the sun's heat would escape and the average temperature of the Earth would drop to –19°C (US Environmental Protection Agency. Greenhouse effects schematic 2001).

1.2 Climate Change and Global Warming

The terms "global warming" and "climate change" are often used to describe the same phenomenon. In actuality they are distinguishable as cause and effect, or problem and consequence. Global warming refers only to the increase in the temperature of the Earth's lower atmosphere as a result of the enhanced greenhouse effect. The resulting impacts of this temperature increase, changes in many aspects of weather, are referring to as climate change. Thus, we are experiencing climate change as a result of global warming. Climate change occurs over decades or longer time-scales. Until now, changes in the global climate have occurred naturally, across centuries or millennia, because of continental drift, various astronomical cycles, variations in solar energy output and volcanic activity. Over the past few decades it has become increasingly apparent that human actions are changing atmospheric composition, thereby causing global climate change (Albritton and Meiro-Filho, 2001).

Climate change encompasses temperature changes on global, regional, and local scales, and also changes in the mean and variability of rainfall, winds, and possibly ocean currents. According to United Nation Framework convention on Climate Change (UNFCC), climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCC, Geneva). During the twentieth century, world average surface temperature increased by approximately 0.6 ° C and approximately two-thirds of that warming has occurred since 1975. Climatologists forecast further warming, along with changes in precipitation and climatic variability, during the coming century and beyond (Albritton *et, al.,* 2001).

Third Assessment Report (2001), the United Nation's Intergovernmental Panel on Climate Change (IPCC) stated: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities and estimated that the global average temperature will rise by several degrees centigrade during this century." Report also projects an increase in average world surface temperature ranging from 1.4 to 5.8^0 C over the course of twenty first century (Paul, 2004).



(Source: Global climate change and health: an old story writ large by A.J. McMichael)

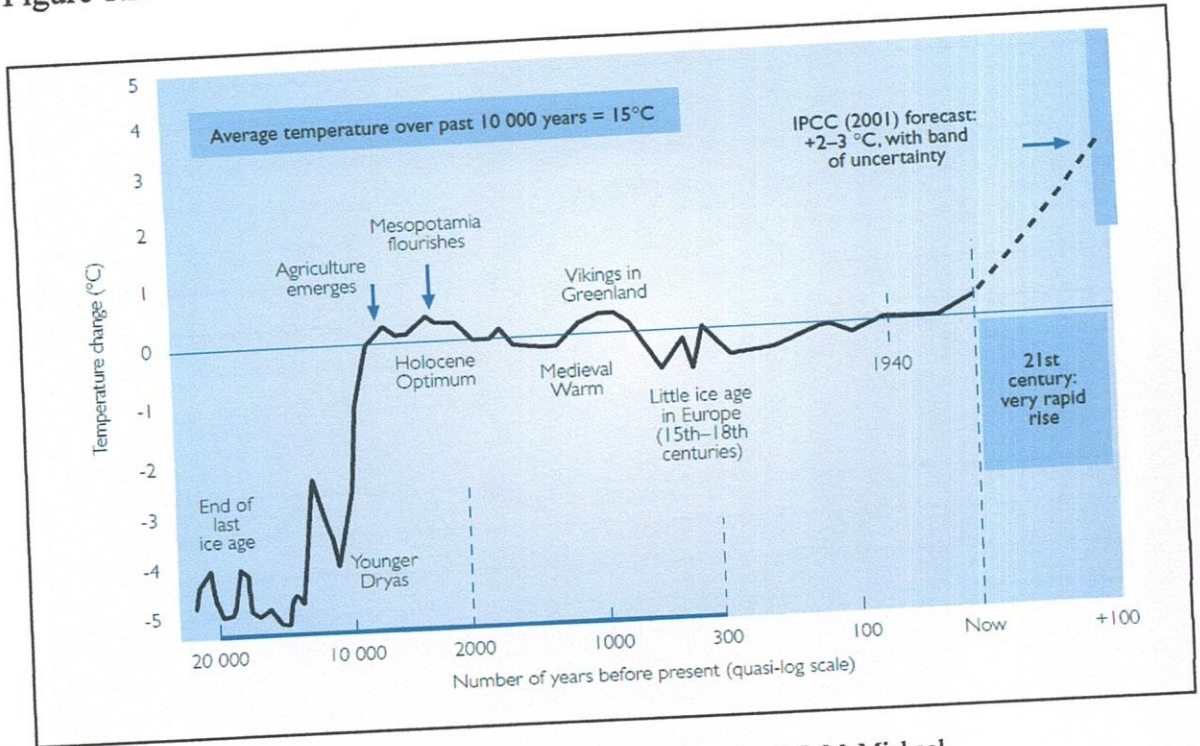
Figure 1.1 Global temperature record, since instrumental recording began in 1860 and proejction for coming century, according to intergovernmental Panel of Climate Change.

1.3 Recent Scientific Assessments on Climate Change

The latest report from the Intergovernmental Panel on Climate Change (IPCC) makes several compellingly clear points (US Environmental Protection Agency, 2001). First, human-induced warming has apparently begun: the particular pattern of temperature increase over the past quarter-century has fingerprints that indicate a substantial contribution from the build-up of greenhouse gases due to human activities. Second, a coherent pattern of changes in simple physical and biological systems has become apparent across all continents—the retreat of glaciers, melting of sea ice, thawing of permafrost, earlier egg-laying by birds, pole wards extension of insect and plant species, earlier flowering of plants and so on. Third, the anticipated average surface temperature rise this century, within the range of 1.4 to 5.8° C, would be a faster increase than predicted in the IPCC's previous major report, in 1996 (Albritton and Meiro-Filho, 2001). The estimated rise in average world temperature over the coming century conceals various important details.

Anticipated surface temperature increases would be greater at higher latitudes, greater on land than at sea, and would affect the daily minimum night-time temperatures more than daily maximum temperatures. Global climate change also would cause rainfall patterns to change with increases over the oceans but a reduction over much of the land surface.

The long history of climatic fluctuations since the end of the last global glaciation around 15 000 years ago, along with the evidence of recent temperature rises and the IPCC's projected rapid warming in the current century, are summarized in Figure 1.2.



Source: Global climate change and health: an old story writ large by A.J. McMichael

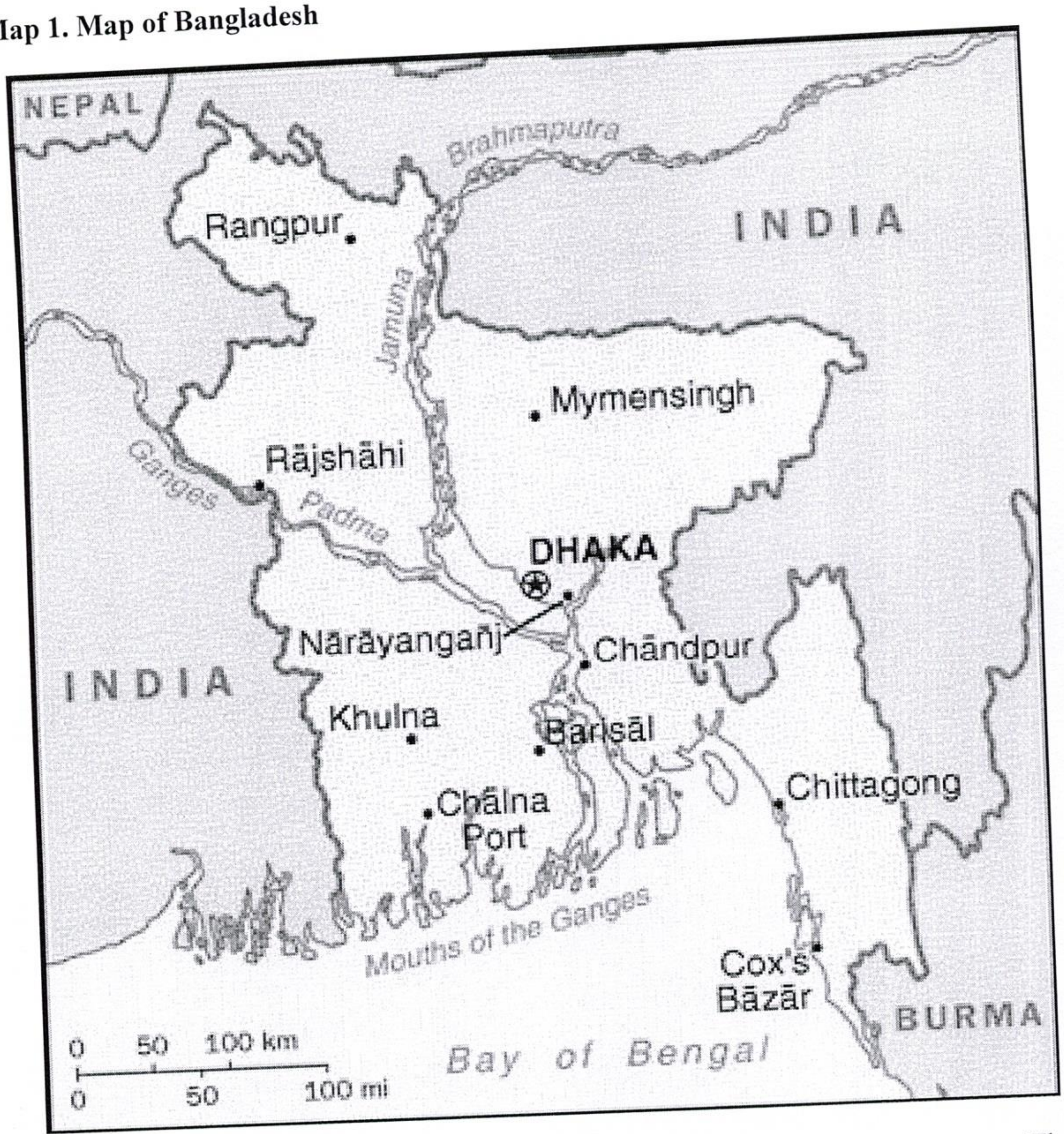
Figure 1.2 Variation in Earth's average surface temperature, over the past 20000 years

1.4 Climate Change in Bangladesh

Bangladesh is located between 20° to 26° North altitude and 88° to 92° East latitude. It is bordered on the west, north and east by India, on the south-east by Myanmar, and on the south by the Bay of Bengal (Map 1). Most of the country is low-lying land comprising mainly the delta of the Ganges and Brahmaputra rivers.

Floodplains occupy 80% of the country. Mean elevations range from less than 1 meter on tidal floodplains, 1 to 3 meters on the main river and estuarine floodplains, and up to 6 meters in the Sylhet basin in the north-east (Rashid, 1991, Ahmed and Mirza, 2000). Only in the extreme northwest are elevations greater than 30 meters above the mean sea level. The northeast and southeast portions of the country are hilly, with some tertiary hills over 1000 meters above mean sea level (Huq and Asaduzzaman, 1999).

Map 1. Map of Bangladesh



Bangladesh ranks low on just about all measures of economic development. This low level of development, combined with other factors such as its geography and climate, makes the country quite vulnerable to climate change. With a population of over 14,97,72,364 people in a small area and a population density of more than 1,209 persons per km, and 71.90% of the population lives in rural areas, Bangladesh is a very densely populated country (World Bank 2010). Higher population density increases vulnerability to climate change because more people are exposed to risk and opportunities for migration within a country are limited.

1.4.1 Review of Climate Change in Bangladesh

The Bangladesh Country Study for the U.S. Country Studies Program used an older version of the Geophysical Fluid Dynamics Laboratory (GFDL) transient model (Manabe *et al.*, 1991) and projected that temperature would rise 1.3°C by 2030 (over mid-20th century levels) and 2.6°C by 2070. The report estimated that winter warming would be greater than summer warming. The study also estimated little change in winter precipitation and an increase in precipitation during the monsoon (Ahmed and Alam, 1998 & Ahmed, 2004). Changes in area averaged temperature and precipitation over Bangladesh were assessed based upon over a dozen recent General Circulation Models (GCM) using a new version of MAGICC/SCENGEN model. MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) is a simple climate model that computes the mean global surface air temperature and used by IPCC to produce projections of future global-mean temperature and sea level rise. SCENGEN is a database that contains the results of a large number of GCM experiments. SCENGEN construct a range of geographically- explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data set.

The results of the MAGICC/SCENGEN analysis for Bangladesh are shown in Table 1.

Table 1 GCM Estimates of Temperature and Precipitation Changes

Year	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
	Annual	DJF[4]	JJA[5]	Annual	DJF	JJA
Baseline average				*2278 mm*	*33.7 mm*	*1343.7 mm*
2030	1.0 (0.11)	1.1 (0.18)	0.8 (0.16)	+3.8 (2.30)	-1.2 (12.56)	+4.7 (3.17)
2050	1.4 (0.16)	1.6 (0.26)	1.1 (0.23)	+5.6 (3.33)	-1.7 (18.15)	+6.8 (4.58)
2100	2.4 (0.28)	2.7 (0.46)	1.9 (0.40)	+9.7 (5.80)	-3.0 (31.60)	+11.8 (7.97)

Note: 4 December, January and February- the winter months of Bangladesh

5 June, July and August- the summer months of Bangladesh

The climate models all estimate a steady increase in temperatures for Bangladesh, with little inter-model variance somewhat more warming is estimated for winter than for summer (Ahmed and Alam, 1998, & Ahmed, 1986). With regard to precipitation - whether there is an increase or decrease under climate change is a critical factor in estimating how climate change will affect Bangladesh, given the country's extreme vulnerability to water related disasters. The key is what happens during the monsoon. More than 80% of the 2,300 mm of annual precipitation that falls on Bangladesh comes during the monsoon period (Smith *et al.,* 1998). Most of the climate models estimate that precipitation will increase during the summer monsoon because they estimate that air over land will warm more than air over oceans in the summer. This will deepen the low pressure system over land that happens anyway in the summer and will enhance the monsoon (Ahmed, 2000). It is notable that the estimated increase in summer precipitation appears to be significant; it is larger than the standard deviation across models. This does not mean that increased monsoon is certain, but increases confidence that it is likely to happen. The climate models also tend to show small decreases in the winter months of December through February. The increase is not statistically significant, and winter precipitation is just over 1% of annual precipitation. However, with higher temperatures increasing evapotranspiration combined with a small decrease in precipitation, dry winter conditions, even drought, are likely to be made worse.

First major work on local level change of temperature and rainfall elements of climate has been undertaken by Climate Change Cell (CCC 2009). They used a model called PRECIS (Providing Regional Climates for Impact Studies), developed by Hadley Center, UK. The model used data from 31 weather stations of Bangladesh and the major findings of PRECIS model are,

- Rainfall during monsoon and post-monsoon periods will increase where it will remain close to historical amount during dry season.
- Rainfall during pre-monsoon will fluctuate in different years.
- Over the country, rainfall will increase 4%, 2.3%, 6.7%, in 2030, 2050, 2070 respectively in reference to the observed baseline period.
- Monthly average maximum temperature will change from 1.2 to 4.7 degrees centigrade in 2030; from 1.2 to 2.5^0 C in 2050 and from 1.2 to 3^0 C in 2070.
- Maximum temperature will increase during monsoon period and it will decrease in other periods.
- Monthly average minimum temperature will increase in all periods and vary from 0.3 to 2.4^0 C in 2030, from 0.2 to 2.3^0 C in 2050 and from 0.6 to 3.3^0 C in 2070.
- Variation of rainfall and temperature (both maximum and minimum) in any location over Bangladesh and in a particular month is quite large than the seasonal and annual average.
- Maximum temperature will increase about 5.97^0 C in Bogra in 2030.

Second major work was also conducted by CCC (2008), where they attempted to characterize changes of Bangladesh climate. They also considered March, April and May as summer and November, December, January and February as winter season. The research showed that the annual and seasonal mean temperatures are found to have in general increasing trends in Bangladesh. The overall trend in mean annual temperature was found to be +0.10 and $+0.21^0$ C per decade for years

1948 to 2007 and 1980 to 2007 respectively. It concludes that warming has been more rapid in recent decades. In addition Rahman *et al.*, 1997 found evidence of changes in monsoon rainfall pattern.

Table 2 All Bangladesh Trends in Seasonal and Annual Mean Temperatures

Season	Trend in all Bangladesh mean temperatures (^{0} C per century) for data period of	
	1948-2007	1980-2007
Winter (Nov-Feb)	+1.67	+1.33
Summer (Mar-May)	+0.26	+2.25
Monsoon (Jan-Oct)	+1.05	+2.44
Annual (Jan-Dec)	+1.03	+2.14

Source: Climate Change Cell (CCC) 2008

1.4.2 Current Climate in Bangladesh

Bangladesh has a humid, warm, tropical climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations. The south-west monsoon originates over the Indian Ocean and carries warm, moist, and unstable air. The monsoon has its onset during the first week of June and ends in the first week of October, with some inter-annual variability in dates. Besides monsoon, the easterly trade winds are also active, providing warm and relatively drier circulation.

In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early-October), Post-monsoon (late-October to November). The general characteristics of the seasons are as follows:

- Winter (December to February) is relatively cooler and drier, with the average temperature ranging from a minimum of 7.2 to 12.8°C to a maximum of 23.9 to 31.1°C. The minimum occasionally falls below 5^{0}C in the north though frost is extremely rare. There is a south to north thermal gradient in winter mean temperature: generally the southern districts are 5^{0}C warmer than the northern districts.

- Pre-monsoon (March to May) is hot with an average maximum of 36.7°C, predominantly in the west for up to 10 days, very high rate of evaporation, and erratic but occasional heavy rainfall from March to June. In some places the temperature occasionally rises up to 40.6°C or more. The peak of the maximum temperatures are observed in April, the beginning of pre-monsoon season. In pre monsoon season the mean temperature gradient is oriented in southwest to northeast direction with the warmer zone in the southwest and the cooler zone in the northeast.
- Monsoon (June to early-October) is both hot and humid, brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall occurring during monsoon. The mean monsoon temperatures are higher in the western districts compared to that for the eastern districts. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours.
- Post-monsoon (late-October to November) is a short-living season characterized by withdrawal of rainfall and gradual lowering of night-time minimum temperature.

The mean annual rainfall is about 2300mm, but there exists a wide spatial and temporal distribution. Annual rainfall ranges from 1200mm in the extreme west to over 5000mm in the east and north-east (MPO, 1991).

1.5 Climate and Human Health

Knowledge of the interactions between climate and health date back to the time of Aristrotole, but our understanding of this subject has recently progressed rapidly as technology has become more advanced.

The Greek physician Hippocrates (about 400 BC) related epidemics to seasonal weather changes, writing that physicians should have “due regard to the seasons of the year, and the diseases which they produce, and to the states of the wind peculiar to each country and the qualities of its waters" (Lloyd G.E.R, 1978). He exhorts them to take note of "the waters which people use, whether they be marshy and soft, or hard and running from elevated and rocky situations, and then if saltish and unfit for cooking," and to observe "the localities of towns, and of the surrounding country, whether they are low or high, hot or cold, wet or dry … and of the diet and regimen of the inhabitants"

Before humans understood that microorganisms caused epidemic diseases, people knew that these diseases were intimately related to climate. For example, ancient Romans retreated to cooler hillside resorts in the summer to avoid malaria.

Global average temperatures are projected to increases, and it is known that climate change in the next hundred years will be significant and by the year 2100 best estimates predict between a 1.8° C and 4° C rise in average global temperature, although it could possibly be as high as 6.4° C (James, 2008). Evidence is mounting that changes in the broad-scale climate system may already be affecting human health, including mortality and morbidity from extreme heat, cold, drought or storms; changes in air and water quality; and changes in the ecology of infectious diseases (Patz, J.A. *et al.,*1996). All over the world, climate change related impacts including prolong flood, heat wave, drought, sea level rise, salinity, temperature and rainfall variations have become very evident (UNDP human development report 2007). People are directly exposed to changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in the quality of water, air and food. These direct and indirect exposures can cause death, disability and suffering (Rahman, 2008 and Shahid, 2009). WHO has estimated that, globally, over 150,000 deaths annually result from recent change in the world's climate relative to the baseline average climate of 1961–1990 (McMichael, *et al.,* 2006). Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) states clearly that climate change is contributing to the global burden of disease and premature deaths (Rahman, 2008).

Climate change also brings new challenges to the control of infectious diseases. Many of the major killers are highly climate sensitive as regards to temperature, humidity and rainfall, including air born (measles) and the water born (diarrhoeal) diseases, as well as diseases including malaria, kala azar, dengue and other infections carried by vectors.

Global climate change would affect human health via pathways of varying complexity, scale and directness and with different timing. Similarly, impacts would vary geographically as a function of both environment and topography and of the vulnerability of the local population. Impacts would be both positive and negative (although expert scientific reviews anticipate predominantly negative). Via climate change humans are contributing to a change in the conditions of life on earth. Climatic influences on health are often modulated by interactions with other ecological processes, social conditions, and adaptive policies. Climate change is one of several concurrent global environmental changes that simultaneously affects human health-often interactively (Watson, R.T. *et al* 1998). The main pathways and categories of health impact of climate change are shown in Figure 1.3.

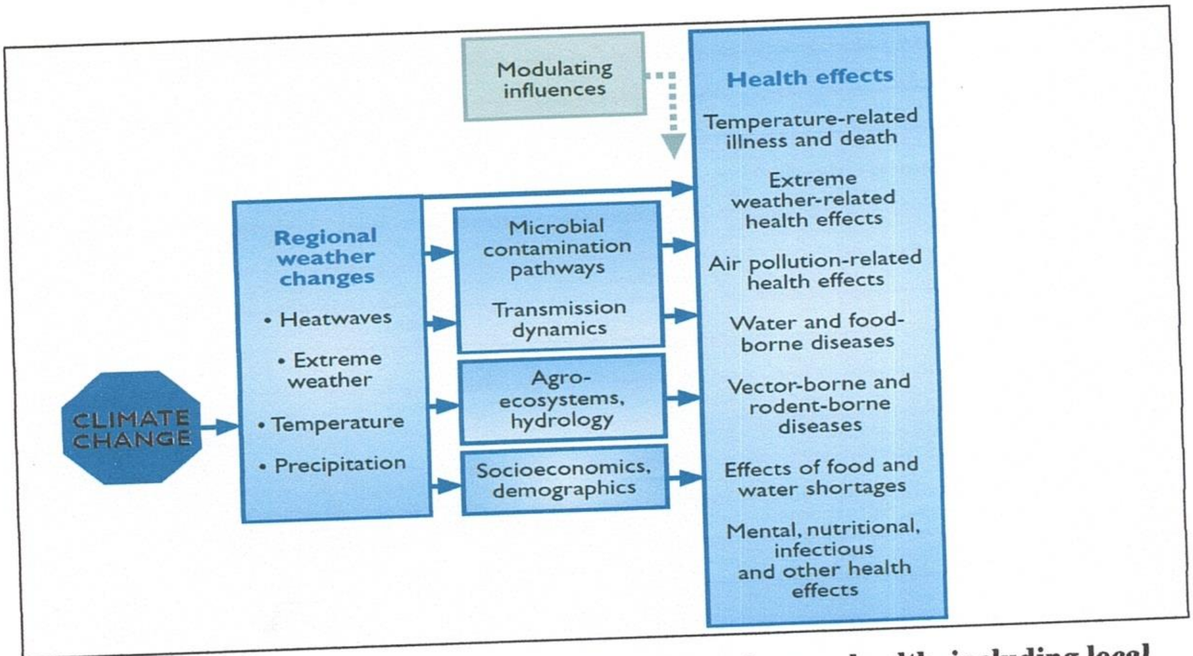


Figure 1.3 Pathway by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures.

(Source: Global climate change and health: an old story writ large by A.J. McMichael)

The more direct impacts on health include those due to changes in exposure to weather extremes (heat waves, winter cold); increases in other extreme weather events (floods, cyclones, storm-surges, droughts); and increased production of certain air pollutants and aeroallergens (spores and molds). Decreases in winter mortality due to milder winters may compensate for increases in summer mortality due to the increased frequency of heat waves.

Climate change, acting via less direct mechanisms, would affect the transmission of many infectious diseases (especially water, food and vector-borne diseases). In the longer term and with considerable variation between populations as a function of geography and vulnerability, these indirect impacts are likely to have greater magnitude than the more direct (McMichael *et al.* 2001 and Epstein *et al.* 1999). For vector-borne infections, the distribution and abundance of vector organisms and intermediate hosts are affected by various physical (temperature, precipitation, humidity, surface water and wind) and biotic factors (vegetation, host species, predators, competitors, parasites and human interventions). Various integrated modeling studies have forecast that an increase in ambient temperature would cause, worldwide, net increases in the geographical distribution of particular vector organisms (e.g. malarial mosquitoes) although some localized decreases also might occur. Further, temperature related changes in the life-cycle dynamics of both the vector species and the pathogenic organisms (flukes, protozoa, bacteria and viruses) would increase the potential transmission of many vector-borne diseases such as malaria (mosquito), dengue fever (mosquito) and leishmaniasis (sand-fly) (Martens, W.J.M. *et al.* 1999).

The effects on human health can be divided into two categories; direct effect on the illness such as heat-shock and on increased mortality in population with other diseases and there is an indirect effect of climate change on health. The major indirect effect is on infectious diseases. Among infectious diseases, vector-born, water-born and air-born infectious diseases are main categories.

1.5.1 International work program on Climate Change and Health

In May 2008, the World Health Assembly (which comprises the 193 Member States of the World Health Organization) passed Resolution No. 61.39 calling on WHO to take systematic action on the global health issue. The resolution called on WHO: "to continue close cooperation with appropriate UN agencies, other agencies and funding bodies, and Member States, to develop capacity to assess the risk from Climate Change (CC) for human health and to implement effective response measures, by promoting further research and projects in this area".

Based on WHO partial estimate of climate change health impacts in the year 2000, an estimated 150,000 deaths currently occur each year in the world's low-income countries from a subject of climate sensitive health outcomes. Around 85% of those deaths are in children (McMichael *et al.,* 2004). Preventing environmental risk could save as many as four million lives a year in children alone, mostly in developing countries. According to a 2003 report authored by WHO, the UNEP and the WMO, climate change is responsible for 2.4 per cent of all cases of diarrhea worldwide and for two per cent of all cases of malaria. Moreover, in the year 2000 an estimated 150,000 deaths were caused by climate change.

1.6 Climate Change and Infectious Diseases Outbreak

The combination of higher temperatures and potential increases in summer precipitation could create the conditions for greater intensity or spread of many infectious diseases. The causes of outbreaks of infectious disease are quite complex and often do not have a simple relationship with increasing temperature or change in precipitation. It is not clear if the magnitude of the change in health risks resulting from climate change will be significant compared to current risks. Global warming will increase the intensity of southwest monsoon, which will, in turn, bring catastrophic ravages like floods and have reaching consequences on health. During and after floods, the water-borne diseases increases due to contamination of surface water. Incidence of vector-borne diseases like malaria, leishmania, dengue are likely to increase as a result of climate change in this region specially in Bangladesh. Increase in temperature may provide better environment for breeding of mosquito and sand fly in places where the temperature were previously bellow optimum. This may increase the human contact with the vectors responsible for spread of diseases. On the whole climate change is expected to present increased risks to human health in Bangladesh, especially in the light of the poor state of the country's public health infrastructure.

Early identification of an infectious disease outbreak is an important first step towards implementation of effective disease interventions and reducing resulting mortality and morbidity in human populations. Outbreak is occurring in every corner of the world. Some are emerging (*e.g.* Nipah) and some are re-emerging (e.g. Kala azar). Some outbreaks make global attention (*e.g.* H1N1, Nipah etc) some are of regional concern or country specific (*e.g.* Diarrhoea, Kala azar etc.). In the majority of the of cases epidemics of infectious disease are generally well under way before authorities are notified and able to control the epidemic or mitigate the effects.

An **infectious disease** is a clinically evident illness resulting from the presence of pathogenic microbial agents, including pathogenic viruses, pathogenic bacteria, fungi, protozoa and multicellular parasites.

A range of infectious (particularly vector-born) diseases are geographically and temporally limited by environmental variables such as climate and vegetation patterns. Climate factor's impact on infectious diseases can be divided into three main effects: on human behavior, on the disease pathogen; on the disease vector, where relevant:

Human Behavior

Climate variability directly influences human behavior, which in turn can determine disease transmission patterns. The strong seasonal pattern of influenza infection in Europe, for example, is thought to reflect human's increase tendency to spend more time indoors during winter months (Halstead, 1996). Also the peak of gastro-enteritis in temperate developed countries during summer months can be related to changes in human behavior associated with warmer temperatures (Altekruse *et al.* 1998).

Disease Pathogens

For infectious diseases where the pathogen replicates outside the final host (i.e. in the environment or an intermediate host or vector), climatic factors can have a direct impact on the development of the pathogens. Most viruses, bacteria and parasites do not replicate bellow a certain temperature threshold *e.g.* 18^0 C for the malaria parasite Plasmodium falciparum and 20^0 C for the Japanese encephalitis virus (Macdonald, 1957, Mellor and Leake, 2000). Ambient temperature increases above this threshold will shorten the development time of the pathogen.

Disease Vectors

The geographical distribution and development rate of insect vectors is strongly related to temperature, rainfall and humidity. A rise in temperature accelerate the insect metabolic rate, increase egg production and makes blood feeding more frequent (Mellor and Leake 2000). The influence of rainfall is also significant. Rainfall has an indirect effect on vector longevity through its effect on humidity. Relatively wet conditions may create favorable insect habitats, thereby increasing the geographical distribution and seasonal abundance of disease vectors. In other cases excess rainfall may have catastrophic effects on local vector populations if flooding washes away breeding sites. Even where linkage between disease and climate are relatively strong, other non-climatic factors also may have a significant impact on the timing and severity of disease outbreaks. One such factor is population vulnerability (*e.g.* influenced by herd immunity and malnutrition). In Kenya, for example, (Shanks *et al.,* 2000) have argued that malaria epidemics in the western highlands may occur only when the non - immune population of the population has grown by recovery, births and immigration because local children surviving to adulthood develop immunity. Human-related factors such as population movements and agricultural practices also can have considerable impact on disease patterns at various scales. For example, the prevalence of malaria and leishmaniasis sometimes is strongly related to irrigation schemes and deforestation (Campbell-Lendrum *et al.,* 2001, and Guthmann *et al.,* 2002)

1.6.1 Classification of Infectious Diseases

Broadly, infectious diseases may be classified into two categories based on the mode of transmission: those spread directly from person to person (through direct contact or droplet exposure) and those spread indirectly through an intervening vector organism (mosquito or tick) or a non-biological physical vehicle (soil or water). Infectious diseases also may be classified by their natural reservoir as anthroponoses (human reservoir) or zoonoses (animal reservoir).

Disease Classifications Relevant to Climate/Health Relationships

Several different schemes allow specialists to classify infectious diseases. The clinical manifestation of the disease is of primary importance for clinicians who are concerned with treatment of infected patients. Alternatively, microbiologists tend to classify infectious diseases by the defining characteristics of the microorganisms, such as viral or bacterial. For epidemiologists the two characteristics of foremost importance are the method of transmission of the pathogen and its natural reservoir, since they are concerned primarily with controlling the spread of disease and preventing future outbreaks (Nelson, *et. al.*). Climate variability's effect on infectious diseases is determined largely by the unique transmission cycle of each pathogen. Transmission cycles that require a vector or non-human host are more susceptible to external environmental influences than those diseases which include only the pathogen and human. Important environmental factors include temperature, precipitation and humidity. Several possible transmission components include pathogen (viral, bacterial, etc.), vector (mosquito, sand fly, snail, etc.), non-biological physical vehicle (water, air, soil, etc.), non-human reservoir (mice, deer, etc.) and human host. Epidemiologists classify infectious diseases broadly as anthroponoses or zoonoses, depending on the natural reservoir of the pathogen; and direct or indirect, depending on the mode of transmission of the pathogen. Figure 1.4 illustrates these four main types of transmission cycles for infectious diseases. The following is a description of each category of disease, discussed in order of probable increasing susceptibility to climatic factors (Wilson, 2001).

Directly Transmitted Diseases

Anthroponoses

Directly transmitted anthroponoses include diseases in which the pathogen normally is transmitted directly between two human hosts through physical contact or droplet exposure. The transmission cycle of these diseases comprises two elements: pathogen and human host. Generally, these diseases are least likely to be influenced by climatic factors since the agent spends little to no time outside the human host. These diseases are susceptible to changes in human behavior, such as overcrowding and inadequate or poor sanitation that may result from climatic changes. Examples of directly transmitted anthroponoses include Measles, Rubella, Tuberculosis (Wilson, 2001).

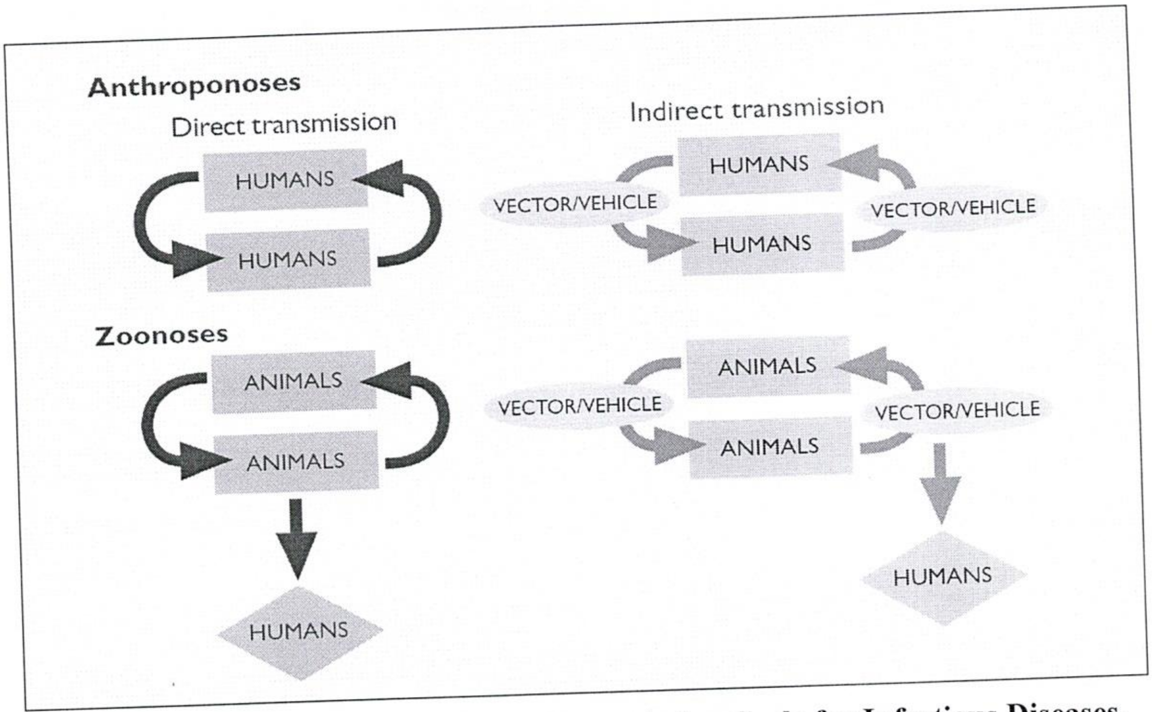


Figure 1.4 Presents four main types of Transmission Cycle for Infectious Diseases.

Indirectly Transmitted Diseases (Anthroponoses & Zoonoses)

Indirectly transmitted anthroponoses are a class of diseases defined by pathogen transmission between two human hosts by either a physical vehicle (*e.g.* soil, water) or a biological vector (*e.g.*tick). These diseases require three components for a complete transmission cycle: the pathogen, the physical vehicle or biological vector, and the human host. Most vectors require a blood meal from the vertebrate host in order to sustain life and reproduce. Indirectly transmitted anthroponoses include leshmaniasis, malaria and dengue fever, whereby the respective leishmania parasite, malaria parasite and the dengue virus are transmitted between human hosts by mosquito vectors (*e.g.* vector-borne disease). Indirectly transmitted water-borne anthroponoses are susceptible to climatic factors because the pathogens exist in the external environment during part of their life cycles. Flooding may result in the contamination of water supplies or the reproduction rate of the pathogen may be influenced by ambient air temperatures (Wilson, 2001). Cholera is an indirectly transmitted water-borne anthroponose that is transmitted by a water vehicle: the bacteria (*Vibrio cholerae*) reside in marine ecosystems by attaching to zooplankton. Survival of these small crustaceans in turn depends on the abundance of their food supply, phytoplankton. Phytoplankton populations tend to increase (bloom) when ocean temperatures are warm. As a result of these ecological relationships, cholera outbreaks occur when ocean surface temperatures rise (Colwell, 1996). Indirectly transmitted zoonoses are similar to indirectly transmitted anthroponoses except that the natural cycle of transmission occurs between nonhuman vertebrates: humans are infected due to accidental encounters with an infected vehicle or vector.

1.6.2 Documented and Predictive Climate/Infectious Disease Linkages

The seasonal patterns and climatic sensitivities of many infectious diseases are well known; the important contemporary concern is the extent to which changes in disease patterns will occur under the conditions of global climate change. Over the past decade or so this question has stimulated research into three concentrations.

First, can the recent past reveal more about how climatic variations or trends affect the occurrence of infectious diseases?

Second, is there any evidence that infectious diseases have changed their prevalence in ways that are reasonably attributable to climate change?

Third, can existing knowledge and theory be used to construct predictive models capable of estimating how future scenarios of different climatic conditions will affect the transmissibility of particular infectious diseases?

Modifying Influences on Infectious Disease

Climate is one of several important factors influencing the incidence of infectious diseases. Other important considerations include socio demographic influences such as human migration and transportation; and drug resistance and nutrition; as well as environmental influences such as deforestation; agricultural development;

water projects; and urbanization. In this era of global development and land-use changes, it is highly unlikely that climatic changes exert an isolated effect on disease; rather the effect is likely dependent on the extent to which humans cope with or counter the trends of other disease modifying influences.

1.6.3 Climate Sensitivities of Infectious Diseases

Both the infectious agent (protozoa, bacteria, viruses, etc.) and the associated vector organism (mosquitoes, ticks, sand flies, etc.) are very small and devoid of thermostatic mechanisms. Their temperature and fluid levels are therefore determined directly by the local climate. Hence, there is a limited range of climatic conditions—the climate envelope—within which each infective or vector species can survive and reproduce. It is particularly notable that the incubation time of a vector-borne infective agent within its vector organism is typically very sensitive to changes in temperature, usually displaying an exponential relationship. Other climatic sensitivities for the agent, vector and host include level of precipitation, sea level elevation, wind and duration of sunlight.

1.6.4 Seasonality of Infectious Diseases

Seasonal change in the incidence of infectious diseases is a common phenomenon in both temperate and tropical climates. However, the mechanisms responsible for seasonal disease incidence, and the epidemiological consequences of seasonality, are poorly understood with rare exception. Seasonal infections of humans range from childhood diseases, such as measles, diphtheria and chickenpox, to faecal–oral infections, such as cholera and rotavirus, vector-borne diseases including malaria and even sexually transmitted gonorrhoea (Gubler, 2001).

Patterns of winter mortality and infectious disease using the example of cyclic influenza and acute respiratory illness outbreaks occurring in the late fall, winter and early spring in North America. This disease pattern may result from increased likelihood of transmission due to indirect social or behavioral 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, diarrheal disease (cholera) outbreaks occur during the monsoon season (Colwell, 1996). In Peru, cyclospora infections peak in the summer and subside in the winter (Madico, *et al.,* 1997). Similarly, some vector-borne diseases (*e.g.* malaria, kala azar 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 (Moore, 1992). Seasonal fluctuations of infectious disease occurrence imply an association with climatic factors. However, to prove a causal link to climate, non-climatic factors must be considered. Furthermore, in order to assess long-term climate influences on disease trends, data must span numerous seasons and utilize proper statistics to account for seasonal fluctuations.

Vector-borne Diseases

Important properties in the transmission of vector-borne diseases include:

Vectors, pathogens, and hosts each survive and reproduce within certain optimal climatic conditions and changes in these conditions can modify greatly these properties of disease transmission. The most influential climatic factors for vector borne diseases include temperature and precipitation but sea level elevation, wind, and daylight duration are additional important considerations.

Temperature Sensitivity

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, and 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, *et al.,* 2001). Disease carrying vectors may adapt to changes in temperature by changing geographical distribution. 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, *et al.,* 1999).

Precipitation Sensitivity

Variability in precipitation may have 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. Vector-borne pathogens spend part of their life-cycle in cold-blooded arthropods that are subject to many environmental factors. Changes in weather and climate that can affect transmission of vector borne diseases include temperature, rainfall, wind, extreme flooding or drought, and sea level rise.

Temperature Effects on Selected Vectors and Vector-borne Pathogens

Vector

- Survival can decrease or increase depending on species;
- Some vectors have higher survival at higher latitudes and altitudes with higher temperatures;
- Changes in the susceptibility of vectors to some pathogens e.g. higher temperatures reduce size of some vectors but reduce activity of others;
- Changes in the rate of vector population growth;
- Changes in feeding rate and host contact (may alter survival rate); and
- Changes in seasonality of populations.

Pathogen

- Decreased extrinsic incubation period of pathogen in vector at higher temperatures;
- Changes in transmission season;
- Changes in distribution; and
- Decreased viral replication.

Effects of Changes in Precipitation on Selected Vector-borne Pathogens

Vector

- Increased rain may increase larval habitat and vector population size by creating new habitat;
- Excess rain or snowpack can eliminate habitat by flooding, decreasing vector population;

- Low rainfall can create habitat by causing rivers to dry into pools (dry season malaria);
- Decreased rain can increase container-breeding mosquitoes by forcing increased water storage;
- Epic rainfall events can synchronize vector host-seeking and virus transmission;
- Increased humidity increases vector survival and decreased humidity decreases vector survival.

Pathogen

Few direct effects but some data on humidity effects on malarial parasite development in the anopheline mosquito host.

Vertebrate host

- Increased rain can increase vegetation, food availability, and population size;
- Increased rain can cause flooding: decreases population size but increases human contact.

1.6.5 Climate Impact on Water Borne Diseases

Climate directly impacts the incidence of waterborne disease through effects on water temperature and precipitation frequency and intensity. These effects are pathogen and pollutant specific, and risks for human disease are markedly affected by local conditions, including regional water and sewage treatment capacities and practices. Domestic water treatment plants may be susceptible to climate change leading to human health risks. For example, droughts may cause problems with increased concentrations of effluent pathogens and overwhelm water treatment plants; aging water treatment plants are particularly at risk. Urbanization of coastal regions may lead to additional nutrient, chemical, and pathogen loading in runoff.

Our understanding of weather and climate impacts on specific pathogens is incomplete. Climate also indirectly impacts waterborne disease through changes in ocean and coastal ecosystems including changes in pH, nutrient and contaminant runoff, salinity, and water security. These indirect impacts are likely to result in degradation of fresh water available for drinking, washing food, cooking, and irrigation, particularly in developing and emerging economies where much of the population still uses untreated surface water from rivers, streams, and other open sources for these needs. Even in countries that treat water, climate-induced changes in the frequency and intensity of extreme weather events could lead to damage or flooding of water and sewage treatment facilities, increasing the risk of waterborne diseases. Severe outbreaks of cholera, in particular, have been directly associated with flooding in Africa and India. A rise in sea level, combined with increasingly severe weather events, is likely to make flooding events commonplace worldwide. Ecosystem degradation from climate change will likely result in pressure on agricultural productivity, crop failure, malnutrition, starvation, increasing population displacement, and resource conflict, all of which are predisposing factors for increased human susceptibility and increased risk of waterborne disease transmission due to surface water contamination with human waste and increased contact with such waters through washing and consumption. Both naturally occurring and pollution-related ocean health threats will likely be exacerbated by climate change. Other climate-related environmental changes may impact marine food webs as well, such as pesticide runoff, leaching of arsenic, fluoride, and nitrates from fertilizers, and lead contamination of drinking and recreational waters through excess rainfall and flooding.

1.6.6 Climate Impact on Vector-borne and Zoonotic Diseases

Vector-borne and Zoonotic Disease (VBZD) ecology is complex, and weather and climate are among several factors that influence transmission cycles and human disease incidence. Changes in temperature and precipitation patterns affect VBZD directly through pathogen host-vector interactions, and indirectly through ecosystem changes (humidity, soil moisture, water temperature, salinity, acidity) and species composition.

Social and cultural behaviors also affect disease transmission. Many VBZD exhibit some degree of climate sensitivity, and ecological shifts associated with climate variability and long-term climate change are expected to impact the distribution and incidence of many of these diseases. Similarly, certain VBZD may decrease in particular regions as habitats become less suitable for host or vector populations and for sustained disease transmission.

1.7 Infectious Diseases and its Prevention and Control

Climate is one of several factors that can influence the spread of infectious disease. Human activities and behaviors also are critical determinants of disease transmission. Climate change is likely to increase the incidence of water-borne, vector-borne and air-borne infectious diseases. Temperature, precipitation and humidity influence the spread of these diseases. Bacteria, parasites, and their vectors may breed faster and live longer in warmer, wetter conditions in Bangladesh. Though biological and technical knowledge are needed to prevent and control the spread of infectious diseases, additional requirements include political will, financial resources and national stability.

The major infectious diseases of Bangladesh are:

1. Viral: Measles, Rubella, Hepatitis A, Hepatitis B, Influenza, Polio, Dengue, Nipah etc.

2. Bacterial: Diarrhoeal disease, Tuberculosis, Tetanus, Pertusis, Meningitis, Diphtheria, Typhoid fever etc.
3. Protozoal: Malaria, Kala azar etc.

1.7.1 Water and Food borne Infectious Diseases

Climate change could cause an increase in the incidence of water- and food borne illnesses in a number of ways. Most of the viruses, bacteria and protozoa that cause water and food borne diseases thrive in warm water and weather. Therefore, increased water and air temperatures could stimulate the growth of harmful pathogens. In addition, increased rainfall events can lead to these pathogens being deposited in water, thereby leading to contamination. According to a study published in the American Journal of Health, for 68 per cent of all waterborne disease outbreaks in the United States between 1948 and 1994, there was a significant association with preceding heavy rainfall events. Water can also become contaminated through surface runoff during a heavy rainfall, which can allow pathogens to find their way into aquifers, wells and drinking water. Drought can also play a role in water contamination. During a drought period there is less runoff flowing into lakes, ponds and streams. This can lead to low water levels, which means that less water is available to disperse and dilute pollutants. Low water levels also mean higher temperature water and increases in the potential for algae growth. Food poisoning is associated with warm weather. During warmer weather people more frequently eat outdoors and may leave foods in the sun without proper refrigeration. Higher temperatures favour the multiplication of harmful bacteria, such as Salmonella. For this reason, a seasonal pattern is often observed, with a peak in cases of food poisoning during the summer months. More than 100 types of pathogenic bacteria, viruses and protozoa can be found in contaminated water, many of which have been implicated in a variety of water and food borne illnesses. Diarrhoea is the common water and food borne disease worldwide.

Diarrhoeal Disease

Diarrhoea is caused by infectious organisms, including viruses, bacteria, protozoa, and helminthes that are transmitted from the stool of one individual to the mouth of another termed the fecal-oral transmission. Diarrhoea is a leading cause of illness and death among children in developing countries, where an estimated 1.3 thousand million episodes and 4 million deaths occur each year in under-fives. Worldwide, these children experience an average of 3.3 episodes each year, but in some areas the average exceeds nine episodes each year. Where episodes are frequent, young children may spend more than 15% of their days with diarrhoea. About 80% of deaths due to diarrhoea occur in the first two years of life. The main cause of death from acute diarrhoea is dehydration, which results from the loss of fluid and electrolytes in diarrhoeal stools.

Diarrhoea is usually defined in epidemiological studies as the passage of three or more loose or watery stools in a 24-hour period, a loose stool being one that would take the shape of a container. However, mothers may use a variety of terms to describe diarrhoea, depending, for example, upon whether the stool is loose, watery, bloody or mucoid, or there is vomiting. The most important causes of acute watery diarrhoea in young children in developing countries are rotavirus, enterotoxigenic Escherichia coli, Shigella, Campylobacter jejuni, and cryptosporidia. In some areas, Vibrio cholerae 01, Salmonella and enteropathogenic *E. coli* are also important causes.

Routes of Transmission

The infectious agents that cause diarrhoea are usually spread by the faecal-oral route, which includes the ingestion of faecally contaminated water or food, person-to-person transmission, and direct contact with infected faeces. Human faeces are the primary source of diarrhoeal pathogens although the animal faces too contain the micro-organisms that can cause diarrhoea. The routes of transmission of water and food borne diseases are shown in figure 1.5.

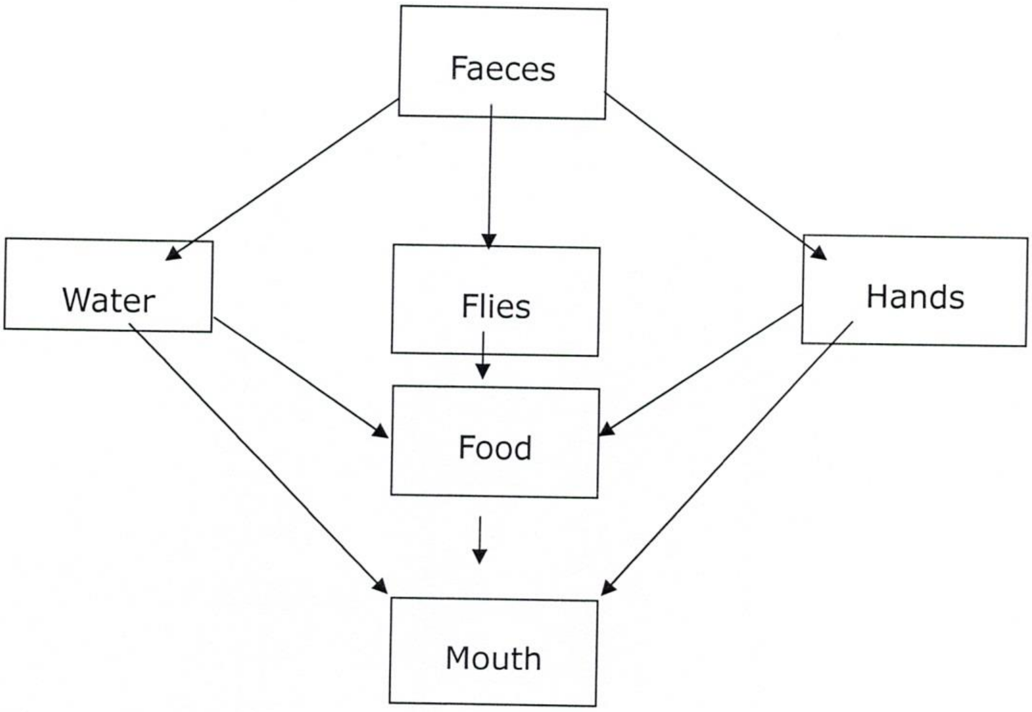


Figure 1.5 Route of Transmission of Water and Food borne Disease

Seasonality

Distinct seasonal patterns of diarrhoea occur in many geographical areas. In temperate climates, bacterial diarrhoea tend to occur more frequently during the warm season, whereas viral diarrhoea, particularly disease caused by rotavirus, peak during the winter. In tropical areas, rotavirus diarrhoea tends to occur throughout the year, increasing in frequency during the drier, cool months, whereas bacterial diarrhoea tend to peak during the warmer, rainy season.

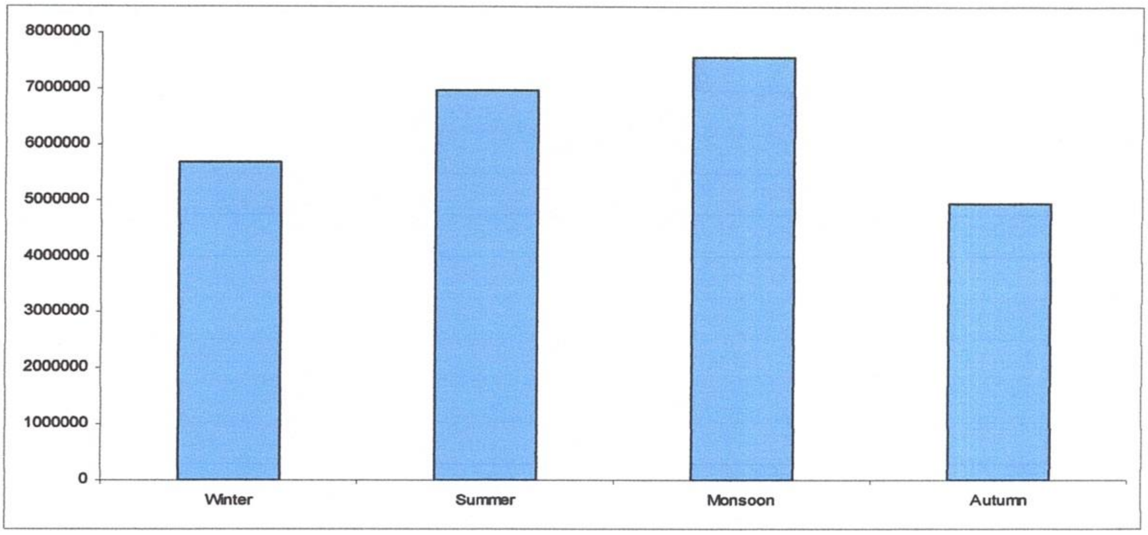


Figure 1.6: showing the seasonal incidence of diarrhoea cases in Bangladesh year 1998-2009.

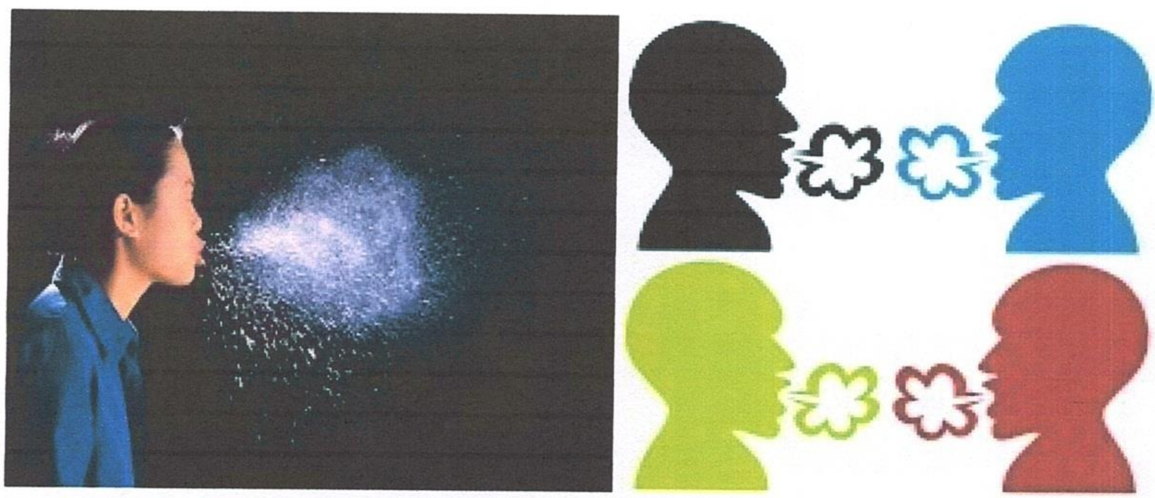
Prevention and Control of Diarrhoea

Although a wide variety of infectious agents cause diarrhoea, they are all transmitted by common faecal-oral pathways, such as contaminated water, food, and hands. Measures taken to interrupt the transmission of the causative agents should focus on these pathways. Important measures of proven efficacy include:

- Giving only breast milk for the first 4-6 months of life;
- Avoiding the use of infant feeding bottles;
- Improving practices related to the preparation and storage of weaning foods (to minimize microbial contamination and growth);
- Using clean water for drinking;
- Washing hands (after defecation or handling faeces, and before preparing food or eating);
- Safely disposing of faeces, including infant faeces; and
- Immunizing against measles and rota virus.

1.7.2 Air borne Infectious Diseases

Pathogens of air borne infectious diseases are normally transmitted directly between two human hosts through physical contact or droplet exposure. The transmission cycle of these diseases comprises two elements: pathogen and human host. Generally, these diseases are least likely to be influenced by climatic factors since the agent spends little to no time outside the human host. These diseases are susceptible to changes in human behavior, such as crowding, schooling, socio-cultural gathering and inadequate sanitation that may result from altered land-use caused by climatic changes.



Source: Infectious Disease Epidemiology, Nelson

Picture 1 Disease Transmission through Respiratory Droplets

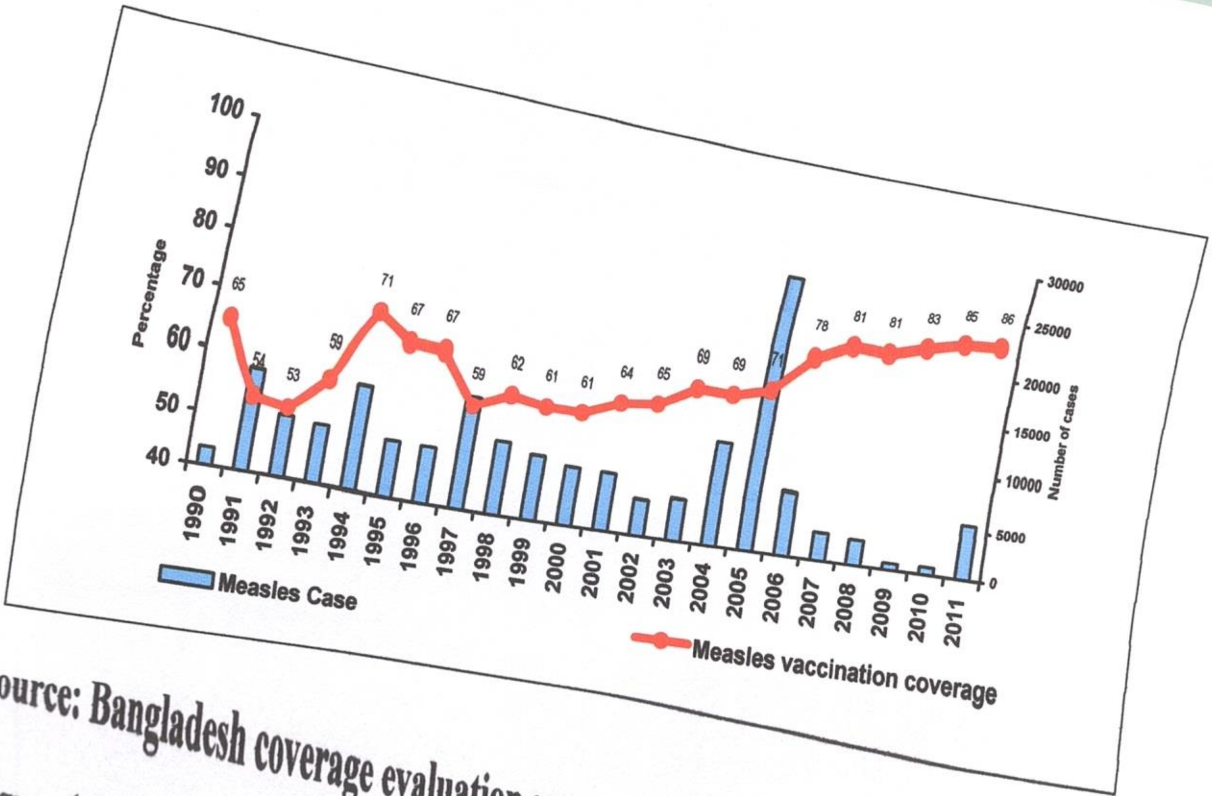
Directly transmitted air borne infectious diseases include measles, rubella, mumps, and tuberculosis (Wilson, 2001).

Measles

Measles is the most contagious disease known to man. It is a major childhood killer in developing countries - accounting for about 900 000 deaths a year. The mean age of infection is about 9-12 months but varies among countries in large part due to differences in passive immunity provided from mother to child through transplacental antibody transfer, childhood nutrition and national vaccination schedules. The measles virus may ultimately be responsible for more child deaths than any other single microbe due to complications from pneumonia, diarrhoea and malnutrition. Measles is a human disease and is not known to occur in animals. Although vaccine initiatives have had considerable success in reducing its impact, measles continues to be a serious global health burden. The disease causes more than 130,000 deaths in 2010, mostly in low-income countries of Africa and Asia (McMichael et al 2006). In addition to being an ongoing threat in the developing world, developed nations that had achieved measles elimination in the 1990's, such as the United States, have recently experienced an increasing number of outbreaks due to decreasing vaccination rates (US Environmental Protection Agency, 2001).

In earlier studies, pre-vaccine measles incidence often exhibited a strong annual or biannual pattern. Epidemics begin as early as September and as late as December or January. The epidemics peak in the spring, often in late March or early April (Fine and Clarkson, 1982).

Measles is a vaccine-preventable disease. Prior to the availability of measles vaccine, measles infected over 90% of children before they reached 15 years of age. Though childhood immunization program has markedly increases its coverage in Bangladesh but still now it is one of the major causes of mortality and morbidity in children. The United Nations selected routine measles vaccination coverage as an indicator of progress towards Millennium Development Goal (MDG4), which aims to reduce the overall number of deaths among children by two-thirds between year 1990 and 2015 (Sustainable Measles Mortality Reduction; Regional Strategic Plan 2007-2010 South East Asia Region, Jul 2007).



Source: Bangladesh coverage evaluation survey 2011

Figure 1.7 Trend of Measles cases and Vaccination Coverage in Bangladesh

Transmission

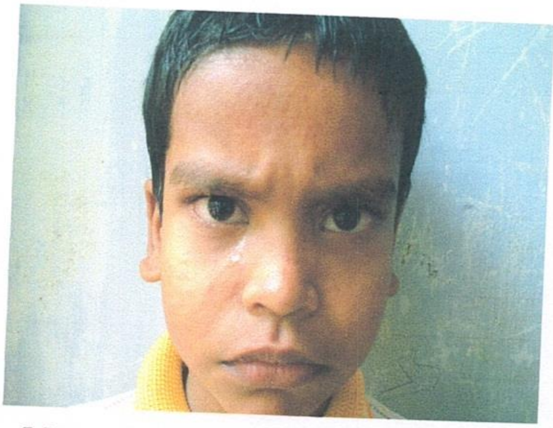
The highly contagious viruses spread by coughing and sneezing, close personal contact or direct contact with infected nasal or throat secretions. The virus remains active and contagious in the air or on infected surfaces for up to two hours. It can be transmitted by an infected person from four days prior to the onset of the rash to four days after the rash erupts. Transmission, which is primarily by large respiratory droplets, increases during the late winter and early spring in temperate climates and after the rainy season in tropical climates.

Measles Outbreak

Measles outbreaks can be particularly deadly in countries experiencing or recovering from a natural disaster or conflict. The major factors that determine the epidemic spread of measles are the accumulation of the susceptible and new migrant that have not suffered from disease in a community and the inevitable exposure to infection. Measles outbreaks can result in epidemics that cause many deaths, especially among young, malnourished children. Epidemics may still occur every 2 or 3 years in areas where there is low vaccine coverage. According to the current measles control strategy of Bangladesh measles outbreak is defined as an occurrence of 3 or more suspected measles cases in one month in a rural ward/urban mahalla.

Signs and Symptoms

The first sign of measles is usually a high fever, which begins about 10 to 12 days after exposure to the virus, and lasts four to seven days. A runny nose, a cough, red and watery eyes, and small white spots inside the cheeks can develop in the initial stage. After several days, a rash erupts, usually on the face and upper neck. Over about three days, the rash spreads, eventually reaching the hands and feet. The rash lasts for five to six days, and then fades.



Source: Measles like diseased children of the study area

Picture 2 Picture of Measles like Cases in the Study Area

Severe measles is more likely among poorly nourished young children, especially those with insufficient vitamin A, or whose immune systems have been weakened by HIV/AIDS or other diseases.

Most measles-related deaths are caused by complications associated with the disease. Complications are more common in children under the age of five, or adults over the age of 20. The most serious complications include blindness, encephalitis, severe diarrhoea and related dehydration, ear infections, or severe respiratory infections such as pneumonia.

Source: Infectious Disease Epidemiology, Nelson
Picture 3 Complication of Measles like Cases

As high as 10% of measles cases result in death among populations with high levels of malnutrition and a lack of adequate health care. People who recover from measles are immune for the rest of their lives.

Prevention and control of Measles

The most effective way to prevent the disease or severe outcomes from the illness is vaccination. Pre-emptive vaccination is the only rational approach to prevent and control the measles disease. Because of the extreme infectiousness of the disease, measures to control outbreaks in highly susceptible communities almost invariably fail. A number of live, attenuated Measles vaccines are available, either as single-antigen vaccines or in combination with either Rubella or mumps and Rubella vaccines. Two doses of the vaccine are recommended to ensure immunity, as about 15% of vaccinated children fail to develop immunity from the first dose. Bangladesh uses live attenuated measles-rubella vaccine in routine EPI and the recommended age for measles-rubella vaccination is from 9 to 11 months (i.e., after completion of 9 months to before the first birthday). & 2nd opportunity of single-antigen live attenuated measles vaccine in routine EPI at the age of 15 to 18 month.

1.7.3 Vector-borne Infectious Diseases

Insects, such as mosquitoes, ticks and fleas, are called "vectors" when they carry diseases that can be passed on to animals or humans. An insect may contact a disease when it bites an infected animal. If the insect then bites a human, the disease is passed from insect to human. Different insects can carry different diseases. Diseases associated with mosquitoes and fleas include malaria, dengue, viral encephalitis and Kala azar. For humans to contract vector-borne diseases usually require three conditions: 1) a human and/or animal "host" for the disease; 2) a large enough population of insects and, 3) a temperature range that supports this population. Present climatic conditions allow for the survival of several vector/rodent-borne diseases. Warmer temperatures associated with climate change may enable vectors and the diseases they carry to extend their ranges and increase their populations. As temperatures increase, the chance of humans contracting the diseases may therefore also increase (Reeves, W.C. 1994).

A changing climate can influence the spread of vector-borne diseases in several ways. Firstly, climate determines the survival rates of bloodsucking insects, particularly mosquitoes, fleas and ticks. For people who live in a cooler climate, it is likely that mosquitoes are not around all year because winter freezing kills many eggs, larvae and adults.

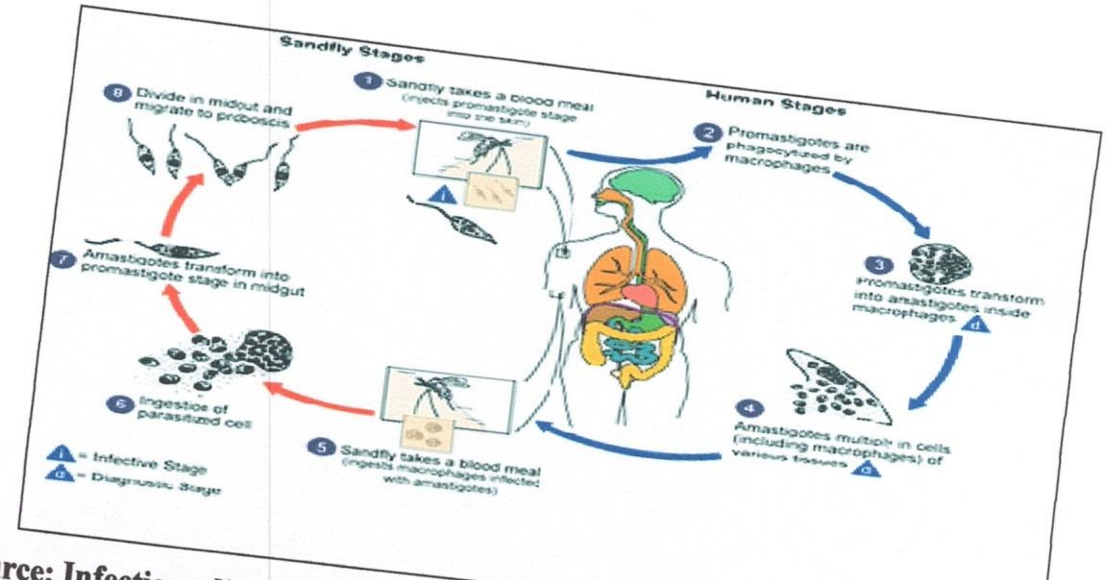
One study at Canada (Bradley, D.J. 1993) found that, in 30°C temperatures, greater than 90 per cent of all mosquitoes contained infection after 12 days; at 18°C, less than 30 per cent contained infection after 28 days. Therefore, diseases will reproduce faster inside the vector as the climate warms. Increases in temperature can also affect vector development and population growth. For example, high temperatures can increase the rate at which mosquito larvae develop into adults. Faster adult development means faster generational turnover, which means more mosquitoes.

Floods- another consequence of climate change could lead to mosquito population booms. After floods recede, they leave behind standing water and puddles perfect breeding grounds for mosquitoes. A growth in the population of mosquitoes would create a greater opportunity for the spread of disease. Longer summers and earlier springs would also extend the mosquito and fleas season.

The major vector borne climate sensitive disease in the study area is visceral leishmaniasis (Kala-azar) and NIPAH virus infection.

Visceral Leishmaniasis (Kala-azar)

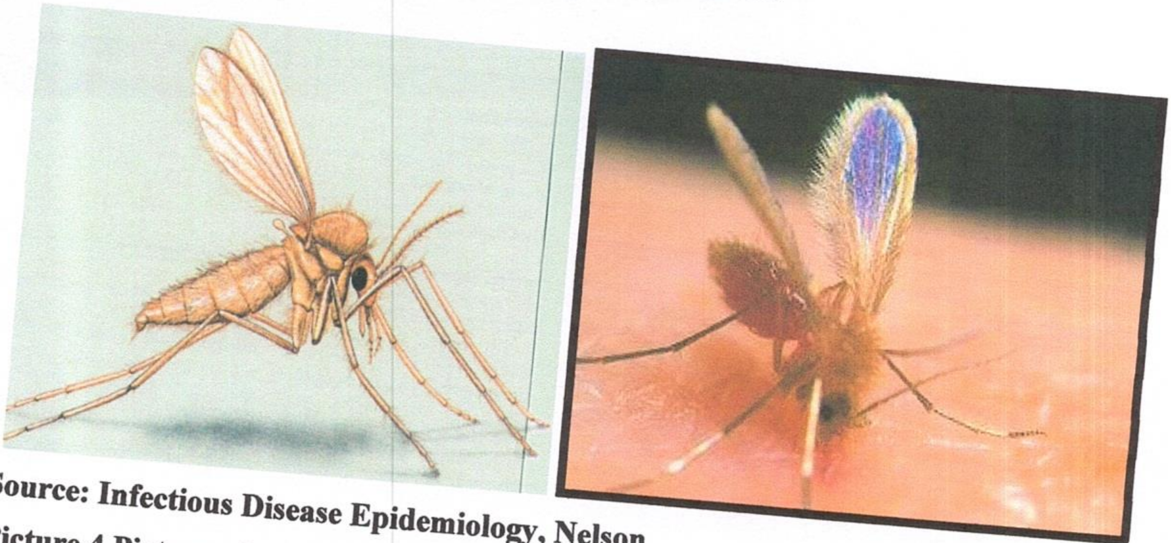
Visceral leishmaniasis (VL), also known as kala-azar, black fever, and Dumdum fever, is the most severe form of leishmaniasis. Leishmaniasis is a disease caused by protozoan parasites of the *Leishmania* genus. This disease is the second-largest parasitic killer in the world (after malaria), responsible for an estimated 500,000 infections each year worldwide. An estimated 147 million people at risk in three countries Bangladesh, India, and Nepal, with about 100,000 cases occurring annually (Goh, 2000). Kala-azar is a re-emerging disease and one of the major public health problems in Bangladesh, and the disease has been endemic for many decades. In Bangladesh about 40 million populations in 139 Upazilas and 45 districts are at risk (study area Rajshahi and Naogaon are within 45 districts). The incidence is about 10,000 cases every year in Bangladesh (Bangladesh Health Bulletin 2012, Chapter 9). The parasite migrates to the internal organs such as liver, spleen (hence '*visceral*'), and bone marrow, and, if left untreated, will almost always result in the death of the host. Signs and symptoms include fever, weight loss, mucosal ulcers, fatigue, anemia, and substantial swelling of the liver and spleen.



Source: Infectious disease epidemiology, Nelson

Figure 1.8: Life-cycle of Kala-azar Parasite

Visceral leishmaniasis (Kala-azar) spreads through an insect vector, the sandfly of the *Phlebotomus* genus. Sandflies are tiny creatures, 3–6 millimeters long by 1.5–3 millimeters in diameter, and are found in tropical or temperate regions throughout the world. Sandfly larvae grow in warm, moist organic matter (such as old trees, house walls, or waste) making them hard to eradicate.



Source: Infectious Disease Epidemiology, Nelson

Picture 4 Picture of Sand Fly

Favorable Conditions for Sand Fly Multiplication are:

- monthly mean temperature between 7.2^0 - 37^0 C;
- mean annual relative humidity (RH) of 70% to 80% RH at least for 3 months;
- annual rainfall of 1250 mm or more;
- altitude < 600 m;
- alluvial soil;
- high sub-soil water; and
- abundant vegetation.

The adult female sand fly is a bloodsucker, usually feeding at night on sleeping prey. When the fly bites an animal infected with *L. donovani*, the pathogen is ingested along with the prey's blood.

Breeding Habit of the Sand Fly (*P. argentipes*)

Breeding places

Source: Study area picture

Picture 5 Breeding Place of Sand Fly

P. argentipes breeds among debris found in the corners of the soil floors of rooms and cattle sheds as well as under the feeding troughs. In outdoor, larvae are found in the cracks of the plinth made up of a mixture of mud cow dung, on the shaded side of huts and cattle sheds.

Resting Habit of the Sand Fly (*P. argentipes*)

Source: Study area picture

Picture 6: Resting Place of Sand Fly

Sand flies are found to rest in cattle sheds in much greater number than in human dwellings. They take shelter in dark corners settling on or under cobwebs, in empty feeding troughs and on any collection of straw or in the cracks and crevices on the walls . They also rest in chicken pens and pigeon holes in small number.

Seasonal variation of Kala- azar

P. argentipes generally disappears during the winter season i.e. November to February. May be some decrease in June due to hot weather followed by an increase with the advent of monsoon. The major peak density occurs in April to May and minor peak densities are found in September to October.

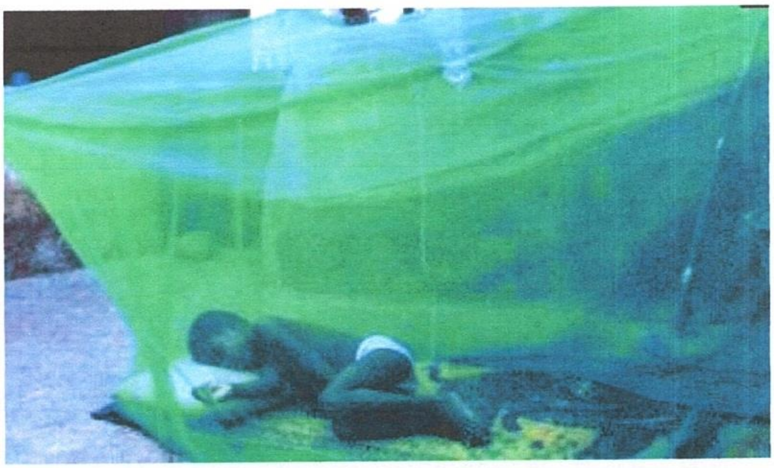
Prevention and control of Kala- azar

In Bangladesh, Kala-azar patients are detected and treated mainly through primary health care centers. ICT based rK39 strip is used for the diagnosis and oral Miltefosine for the treatment of cases.

There is no vaccine for this disease.

Integrated vector management and environmental control is the main way to prevent and control of this disease:

- Indoor Residual Spray (IRS)-Two round a year (March-April & August-September). Suitable chemical is pyrethroid



Source: Study area picture

Picture 7 Insecticide Treated Nets with Synthetic Pyrethroid

- Micro environmental Management through improved housing and living conditions and reducing sand fly breeding places.

1.7.4 Emerging and Re-emerging Infectious Disease

Along with growing concern about the spread of existing diseases, comes the threat of the introduction of new diseases as a result of warmer temperatures. For a disease to be introduced to a region, the climate must be favorable for survival of both the vector and the pathogen. An emerging or re-emerging infectious disease is a disease whose incidence has increased in a defined time period and location. If the disease was unknown in the location before, the disease is considered to be emerging. However, if the disease had been present at the location in the past and was considered eradicated or controlled, the disease is considered to be re-emerging. Many of these emerging diseases are zoonotic, and rely on animal populations as reservoirs of infection. Most emerging infections are caused by pathogens already present in the environment, brought out of obscurity or given a selective advantage by changing conditions and afforded an opportunity to infect new host populations. These changes include ecological changes, such as those due to human activities or to anomalies in climate; demographic changes and behavior; travel and commerce; technology and industry; microbial adaptation and change; and breakdown of public health measures. Many factors precipitate emergence by placing humans or animals in contact with a natural reservoir or host for an infection unfamiliar but already present (often a zoonotic or arthropod-borne infection), either by increasing proximity or, often, also by changing conditions so as to favor an increased population of the microbe or its natural host (Morse, 1996). Diseases considered to be emerging or re-emerging include avian influenza, SARS, Nipah, Chikongunia and Malaria.

Nipah Virus Infection

Human Nipah virus (NIV) infection, an emerging zoonotic disease, caused by Nipah virus originating from an new genus – the Henipa virus (Chua *et al.,* 2000-2003). *Pteropus* bats (Fruit bats) are the zoonotic host of the virus and pigs are the likely amplifying host.

Picture 8 Picture of *Pteropus* Bats

Human infections range from asymptomatic infection to fatal encephalitis. Infected people initially develop influenza-like symptoms of fever, headaches, myalgia (muscle pain), vomiting and sore throat. This can be followed by dizziness, drowsiness, altered consciousness, and neurological signs that indicate acute encephalitis. Some people can also experience atypical pneumonia and severe respiratory problems, including acute respiratory distress. Encephalitis and seizures occur in severe cases, progressing to coma within 24 to 48 hours. The case fatality rate is estimated at 40% to 75%; however, this rate can vary by outbreak depending on local capabilities for surveillance investigations.

Natural host: Fruit bats of *Pteropus* family

Transmission

During the initial outbreaks in Malaysia and Singapore, most human infections resulted from direct contact with sick pigs or their contaminated tissues. Transmission is thought to have occurred via respiratory droplets, contact with throat or nasal secretions from the pigs, or contact with the tissue of a sick animal. In

Table 3 Shows Morbidity and Mortality due to Nipah or Nipah like Viral Encephalitis in Bangladesh during the period from 2001 to 2011

Year/Month	Location	No. of cases	No. of deaths	Case-fatality rate (%)
April-May 2001	Meherpur	13	9	69
January 2003	Naogaon	12	8	67
January 2004	Rajbari	31	23	74
April 2004	Faridpur	36	27	75
Jan-March 2005	Tangail	12	11	92
Jan-Feb 2007	Thakurgaon	7	3	43
March 2007	Kustia, Pabna, Natore	8	5	63
April 2007	Naogaon	3	1	33
February 2008	Manikgonj	4	4	100
April 2008	Rajbari and Faridpur	7	5	71
January 2009	Gaibandha, Rangpur, Nilphamary Rajbari	3 1	0 1	0 100
Feb-Mar 2010	Faridpur, Rajbari, Gopalgonj and Madaripur	16	14	87.5
Jan-Feb 2011	Lalmonirhat, Dinajpur, Nilphamari and Rangpur	44	40	83

Prevention and Control of Nipah Infection

There are currently no drugs or vaccines available to treat Nipah virus infection. Intensive supportive care with treatment of symptoms is the main approach to managing the infection in people. In the absence of a vaccine, the only way to reduce infection in people is by raising awareness of the risk factors and educating people about the measures they can take to reduce exposure to the virus.

- Reducing the risk of bat-to-human transmission. Efforts to prevent transmission should first focus on decreasing bat access to date palm sap. Freshly collected date palm juice should also be boiled and fruits should be thoroughly washed and peeled before consumption.

- Reducing the risk of human-to-human transmission. Close physical contact with Nipah virus-infected people should be avoided. Gloves and protective equipment should be worn when taking care of ill people. Regular hand washing should be carried out after caring for or visiting sick people.

1.8 Background on Climate Change and Health Impacts in Bangladesh

Bangladesh is one of the countries which have been significantly affected by natural disasters. In recent times natural hazards are more frequent and intense. It is now accepted, mainly by the IPCC scientists and national governments, that this climatic hazards are the results of climate change at global and regional level. IPCC states in their third (2001) and fourth assessment (2007) reports that the global average surface temperature has already increased by 0.6^0 C (+/- 0.2^0 C) during last 140 years and 0.74^0 C (+/- 0.18^0 C) during the last 100 years respectively and likely to increase from 1.4 to 5.8^0 C by 2100. For Bangladesh, the projections show that by 2030, a 0.7^0 C temperature raise in monsoon season and a 1.3^0 C rise in the winter season might take place.

According to IPCC (2001), global warming would cause increase of vector borne and water borne diseases in the tropics (IPCC, 2001). All around the world, increased natural, technological and human induced hazards have brought along frequent epidemics, increased number of deaths, injuries and health problems of the human beings. Moreover, non-climatic issues including poor housing, lack of safe water and sanitation facilities, inadequate or improper health care services would increase the adversity of health problems. Many scientists have already anticipated that more frequent and more intense or severe weather events will result in increased deaths, injuries and diseases in developed countries like Canada, but the biggest impact will be felt in low-lying, heavily populated areas such as Bangladesh, particularly when coupled with sea level rise (Canadian Association of Physicians for the Environment, 2006). Estimation shows that at least 3,000 million people of all tropical countries are exposed to the risk of dengue while 2,400 million tropics and subtropics are at risk of malaria (IPCC, 2001; Githeko and Woodward, 2003). Other sources estimate that climate change causes 2.4 per cent of all cases of diarrhoea worldwide and 2 percent of all cases of malaria (WHO, 2006). It was also estimated that climate changes was responsible for at least 150,000 deaths and 5.5 million Disability Adjusted Life Years in the year 2000.

The arrogant Himalayas in the north and funnel shaped Bay of Bengal in the south have made a meeting place of the life giving monsoon rains and the catastrophic devastation of floods, cyclones, storm surges, droughts etc. (Paramanik, 1991). A recent study shows that at least 174 natural disasters affected Bangladesh from 1974 to 2003 (Sapir *et. al.,* 2004). Extreme events such as floods, drought and cyclone etc. directly and indirectly affect health of people of this country almost every year. For example, the total death caused by flood in 2004 was about 800 while cyclone of 1991 killed 138,000 people of Bangladesh (ADB, 2004; BCAS, 1991).

Bangladesh is already vulnerable to outbreaks of infectious, water borne and other types of diseases (World Bank, 2000). Other diseases like diarrhoea, dysentery, etc. are also on the increasing trend especially during the summer months. It has been predicted that the combination of higher temperatures and potential increase in summer precipitation may cause spread of many infectious diseases (MoEF, 2005).Climate change also brings about additional stresses like dehydration, malnutrition and heat related morbidity especially among children and the elderly. These problems are thought to be closely interlinked with water supply, sanitation and food production. Climate change has already been linked to land degradation, freshwater decline, biodiversity loss and ecosystem decline, and stratospheric ozone depletion. Changes in the above factors may have a direct or indirect impact on human health as well.

There were some researches and studies on climate change and its impacts in Bangladesh at different times by both government and non-government organizations/institutions. But research on human health impacts due to climate change in Bangladesh has not gained much focus before 2006. Climate Change Cell (CCC) under Comprehensive Disaster Management Programme (CDMP) has brought climate change and health as priority issue for research in 2006.

In order to have a better understanding of the possible link between climate change and human health this study will give us a better picture of present status of infectious disease burden of the districts concerned. Understanding the burden of these diseases can inform rational allocation of health resources and also to take special initiatives to improve the situations. So the present research may provide the linkage between climate change and infectious disease outbreak in children that will helps environmentally friendly public health interventions.

1.9 Objectives of the Study

The overall objective of the study is to find out the impact of climate change on the outbreak of infectious diseases among children in Bangladesh: its prevention and control. However, the specific objectives are:

- To investigate the factors related with occurrences of diseases among children in relation to climate changes.
- To investigate the outbreak of diseases among children in relation to climate changes.
- To estimate the occurrences of vaccine preventable disease and determine their extent and distribution.
- To assess the pattern of climatic change in the study areas.
- To compare the climate sensitive disease pattern with seasonal variation.
- To evaluate the immunization status of children in the study areas.

Chapter Two
Materials and Methods

The methodology of the study includes analysis of both secondary and primary data. This was a cross sectional comparative study. Infectious disease related data were collected from twenty Upazila Health Complex, one district hospital, two Civil Surgeon office and one City Corporation of the study area Rajshahi and Naogaon district and also from MIS of DGHS, Dhaka. Time series of climate factors data were collected from Bangladesh Meteorological Department Dhaka and from local weather station, Rajshahi for the period of years 1964 to 2011. Primary data were collected from the study area for the period of years 2009 to 2011. All collected data were analyzed by using computed based statistical software SPSS 19. Pc program, and expressed as mean ± SD or in frequency or in percentage. The level of significance was expressed in p value and p value <0.05 was considered as a level of significance. Result used to find out the correlation association between climatic variables temperature, rainfalls and incidence of infectious diseases (diarrhoea, measles, kala-azar). In addition, immunization status and incidence of vaccine preventable infectious disease also analyzed. Primary data collection tools include household survey, active case search at hospital facilities and in-depth interview with diseased individual or from attendant. The systemic random sampling technique was carried out in the household of the study areas. A total of 60 clusters including 420 samples were selected according to probability proportional to size (PPS) methods which is self-weighted. The main purpose of primary data collections were to collect the data on infectious disease, vaccination status of the children, perception on climatic variables (temperature, rainfall), seasonal changes of climatic factors etc.

2.1 Descriptions of the Study Area

Rajshahi District

Rajshahi district is a district in north-western Bangladesh and a part of the Rajshahi Division. Rajshahi has one city corporation, 9 upazilas, 71 unions, 1678 mauzas, 306 mahallas and 1727 villages. Upazillas of Rajshahi are: Bagha, Bagmara, Charghat, Durgapur, Godagari, Mohanpur, Paba, Puthia and Tanore.

Map 2 Map of Rajshahi district

It lies between 24°07′ to 24°43′ north latitudes and between 88°17′ to 88°58′ east longitudes. The total area of the District is 2,425.37 sq. km. Rajshahi District is bounded by Naogaon District on the north, West Bengal of India, the Padma and Kushtia District on the south, Natore District on the east and Chapainawabganj District on the west. The region consists of Barind tract, Diara and Char lands.

Rajshahi town (City Corporation) stands on the bank of the river Padma. The area of the Rajshahi City Corporation is 96.72 sq km.

Households and Population: According to the Population Census 2011, total number of households of Rajshahi district was 633,758 and total enumerated population was 2,595,197. Among the nine upazilas, Mohanpur had the lowest population of 170 thousand while Bagmara had the highest population of 355 thousands. Sex ratio Male/female was 102/100.

Climate: The district bears a moderate and pleasant climate. The temperature, humidity and coldness of the district are not high. The summer season commences from April and continues up to the end of June. The rainy season comes at the end of June and stays up to September. The winter season starts from the middle of November and lasts up to the end of February. The minimum and maximum mean temperature during winter varies from $9^{\circ}c$ to $14^{\circ}c$. During summer the minimum and maximum mean temperature, vary from $25.5^{\circ}c$ to $38.7^{\circ}c$. The rainfall is heavy during July to September. The annual rainfall of the district recorded in 2011 was 1862 millimeters. The level of humidity was about 77 % in April and about 88 % in July.

Main Rivers: There are ten rivers; main rivers are Padma (Ganges), Mahananda, Baral and Barnai.

Religion: Muslim 93%; Hindu 5%, Christian 1.5% and others 0.5%.

Ethnic national: Santal 2.34%.

Main occupations: Agriculture 38.73%, agricultural labourer 23.64%, commerce 12.44%, service 8.81% etc.

Main crops: Paddy, wheat, jute, sugarcane, turmeric, oil seed, onion, garlic, potato, betel leaf and mulberry plant. (Source: "The District Statistics 2011"; Bangladesh Bureau of statistics census 2011)

Naogaon District Information

Naogaon district is situated in the Northern Bangladesh within the jurisdiction of Rajshahi Division. The district is bounded on the north by India, on the east by Joypurhat and Bogra districts, on the south by Natore and Rajshahi Districts and on the west by Nawabganj and India. The total area of the district is 3,435.65 sq. km. (1326.51 sq. miles) of which 9.09 sq.km. (3.51 sq. miles) is riverine and 19.45 sq.km (7.51 sq. miles) is under forest. The district lies between 24°32' and 25°13' north latitudes and between 28°23' and 89°10' east longitudes. The district consists of 11 upazilas, 99 unions, 2565 mauzas, 2779 villages, 3 paurashavas, 27 wards and 92 mahallas. The upazilas are Naogaon Sadar, Atrai, Badalgachhi, Dhamoirhat, Manda, Mahadevpur, Niamatpur, Patnitala, Porsha, Raninagar and Sapahar.

Map 3 Map of Naogaon district

Weather: The annual average temperature of this district varies from maximum 37.8°C to minimum 11.2°C. The annual average rainfall is 1862 mm.

Major rivers: Atrai, Punorvoba, Nagor, little jamuna, Chiri and Tulsiganga. **Population:** 2,600,000. Sex ratio Male/female was 100/100.

Religion: Muslim 84.51%, Hindu 11.39%, others 4.1%

Ethnic community: Santal, Oraon , Munda, Mahali, Bansphor and Kurmi.

Main occupations: Agriculture 49.01%, agricultural laborer 26.96%, commerce 8.35% etc.

Main crops: Paddy, potato, watermelon, oil seeds, pulses etc.

Main exports: Paddy, rice and potato.

Economic importance of Naogaon:

Naogaon is considered as the storage of food supply for Bangladesh. Here, local peoples are mostly farmer. (Source: "The District Statistics 2011"; Bangladesh Bureau of statistics census 2011)

2.2 Secondary Data Collection

A number of health related documents and climate change data were collected from concerned local, regional and national sources. Time series (Year 1964 to 2011) temperature and rainfall data were collected from Bangladesh Meteorological Department (BMD) Dhaka and local weather station Rajshahi. It is also essential to mention that there were some missing data in some months. Data were considered to be missing when the data were not recorded. To maintain the continuity, the gaps were filled up by the time mean values of the existing years. Health related documents were collected from MIS of Director General of Health Services (DGHS) of Ministry of the Health and Family Welfare of the Government of Bangladesh (GoB). Disease records were collected from Upazila Health

Complexes (UHC), Sadar Hospital, City Corporation, Municipality and Civil Surgeon Office. Data of diseases for 12 years were available from the records.

2.3 Primary Data Collection

Multiple methods were used to collect primary data. These are as follows:

- Sample survey
- In-depth Interview during outbreak investigation and searching

Sample Survey

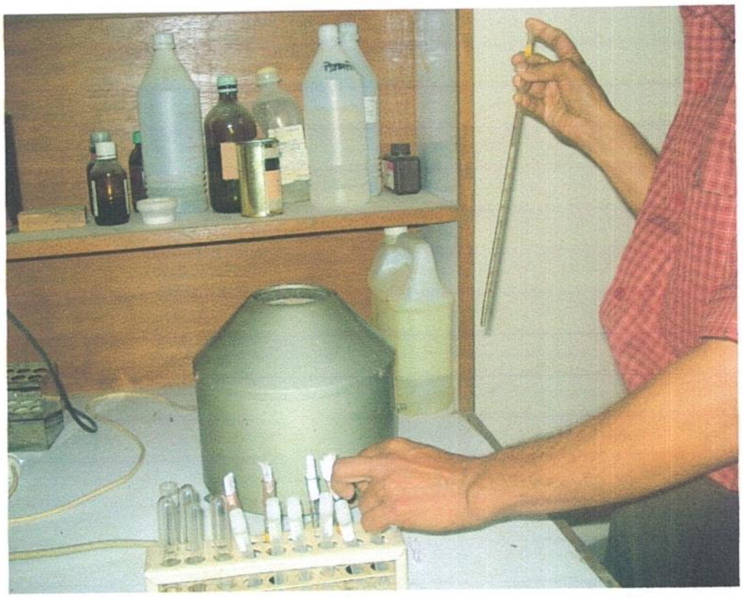
The sample survey was designed to assess the vaccination status of 9 months to under 5 years children with socio-demographic and climatic factors information of the study districts. The sample survey was carried out in the households of the villages/mouzas of nine Upazila and one City Corporation of Rajshahi district and eleven Upazila and one municipality of Naogoan district. The sample size of the survey was determined by the survey units independently by using WHO 30 cluster coverage survey sampling technique. From each survey district, 30 clusters were selected following the systemic random sampling techniques from the list of Mouzas and Mahallas (Appendix V, VI) available with Bangladesh Bureau of Statistics (BBS) following probability proportional-to-size (PPS) method. Using the 30-cluster survey sampling technique, 30 clusters were taken from each district and a total of 60 clusters were selected. Seven subjects were selected from each cluster thus, a total of 420 samples were covered for the survey area. Cluster survey was started from the central part of the village /mouza, direction and household were chosen randomly and interviews were conducted in consecutive households for 7 eligible respondents (household having 9 months to under 5 years children) along with information on the age composition of target samples and the total household population. Mother of the child was given priority to respond to the questions. In absence of mother other senior persons of household were requested to respond. Sometime they all discussed before responding to some question particularly on health disorders and climate change issues. The questionnaire generally focused on the vaccination status of the children, education and occupation of parents, knowledge about climate change and infectious disease, experiences of Infectious disease within one year and monthly family income.

The questions were both open and closed ended (Annex-i). For this study, a total of 60 clusters were selected from the study area and 420 sample respondents were surveyed.

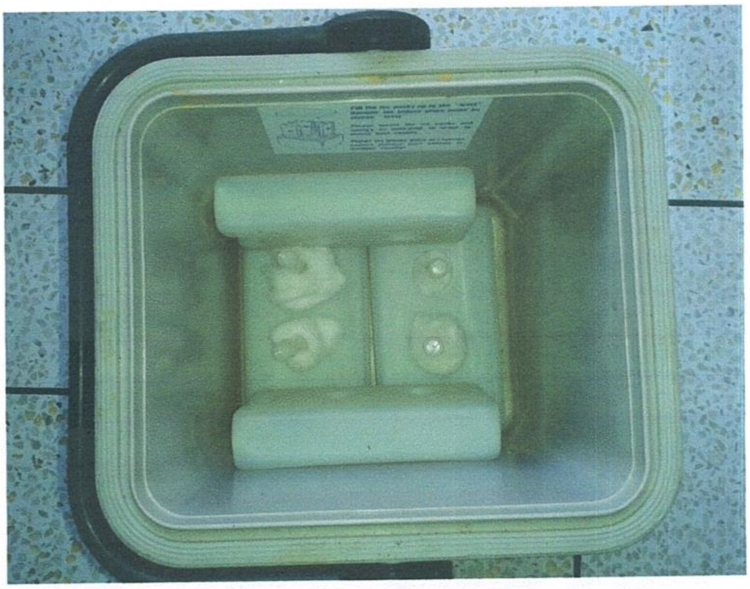
In-depth Interview

A prescribed format used to collect weekly infectious disease report from the Upazila health complex, district hospital and NGO facilities of the survey area. Active case search at government and NGO facilities and used standard case definition of the diseases for diagnosis, notification and declaration of an outbreak. In-depth interviews were taken from the diseased individual or from attendant about clinical course of disease, time of onset of disease, epidemiological linkage i.e. contact with previously positive cases, knowledge about climate change and vaccination status of the patient.

In response to notification of an outbreak of disease by local health authorities a pre investigation orientation was arranged for the search team, comprising of field worker and investigator himself. Investigator assists to train the team with objectives of the outbreak investigation, case definition, blood sample collection from diseased person, methods of data collection including the prescribed forms (Annex-iii, iv). The door to door approach was adopted throughout the outbreak notified rural and urban ward to collect the data.



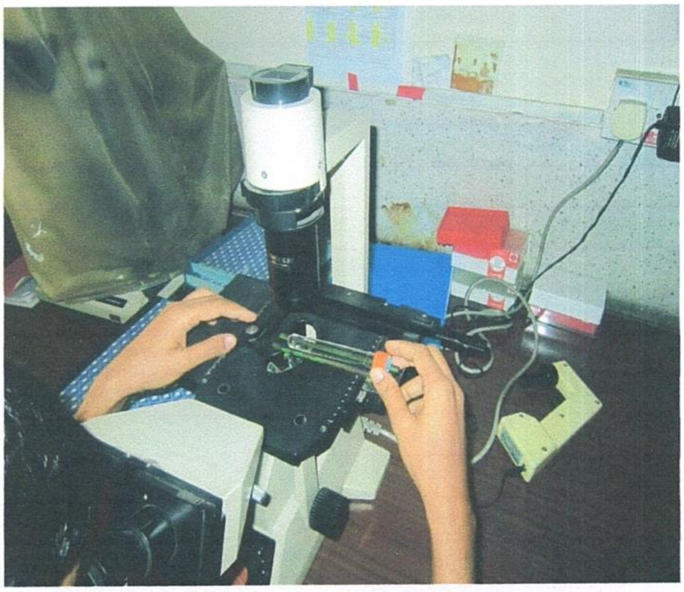
Picture 9 Blood sample centrifuging to prepare serum



Picture 10 Cold chain box with centrifuged serum for transportation

After collection of blood sample from the patient suffering from measles like disease, serum was separated by centrifuge machine and shifted in to special sterilizing container. For serum separation blood sample was settled for half an hour and spanned in centrifuge machine for 20 minutes. Then sterilizing container with 1 ml serum labeled properly and was placed into cold box. With maintaining cold chain (+2^{0}C to +8^{0}C) specimen sent to Institute of Public Health for testing.

Measles and Rubella Immunoglobulin "M" (IgM) identifying reagent was used in the laboratory.



Picture 11 Serum sample tested for measles and rubella specific IgM antibody

Immunization status observation method

For protection against the eight deadly childhood diseases, namely tuberculosis, diphtheria, pertusis, tetanus, Hepatitis-B (Hep-B), Hemophylus Influenza Type-B (Hib), poliomyelitis and measles, WHO recommends that each child be immunized with one dose of BCG against tuberculosis, three doses of Penta against diphtheria, pertussis, Hep-B, Hib and tetanus, four doses of Oral Polio Vaccine (OPV) against poliomyelitis, and one dose of Measles vaccine against measles. The government of Bangladesh has approved the following schedule: BCG at or after birth; Penta1/OPV1 at the age of six weeks or after; Measles vaccine at the age of 270 days or after. The interval between the consecutive doses of Penta/OPV should be four weeks or more meaning that Penta2/OPV2 should be given four weeks or more after Penta1/OPV1 and Penta3/OPV3 should be given four weeks or more after Penta2/OPV2.

To assess the vaccination status of children in the study area, only valid vaccination coverage was assessed. Valid coverage was assessed in terms of valid doses of any vaccine administered to a child by age of one year. A valid dose was a recommended dose of a recommended vaccine administered in a recommended age and or intervals. Considering the above schedule vaccination related information's were collected from 60 clusters of study districts through house hold survey.

Chapter Three
Results

The study area Rajshahi and Naogaon are the western districts known as barind area in Bangladesh and poses drought prone plane, riverine and low lands. Time series data on climate factors like temperature and rainfall of Rajshahi meteorological station and infectious diseases data/information specially climate sensitive diseases *viz.* diarrhoea, malaria, dengue, measles, kala azar and Nipah virus infection were considered for interpreting their correlations as described below:

Analysis of Secondary data

3.1 Climate Characteristics (Temperature and Rainfall)

The time series climatic data comprised monthly and annual mean, maximum and minimum temperature for the period of 1964-2011 and monthly and annual mean rainfall for the period of 1964-2011. The data were analyzed to find the seasonal, intra-seasonal and annual changes.

The long-term changes of annual maximum, mean and minimum temperature of study area over the study period (1964-2011) (Figure 3.1), (Appendix-1- 3) found to have in general increasing trends in annual mean and annual mean minimum temperature but the mean maximum temperature slightly was decreasing in recent past decades. The study revealed that through the last 47 years (1964-2011) the annual mean temperature, annual mean minimum temperature has increased by 1.1^0 C and 3.5^0 C respectively but the annual mean maximum temperature has decreased by 4.7^0C.

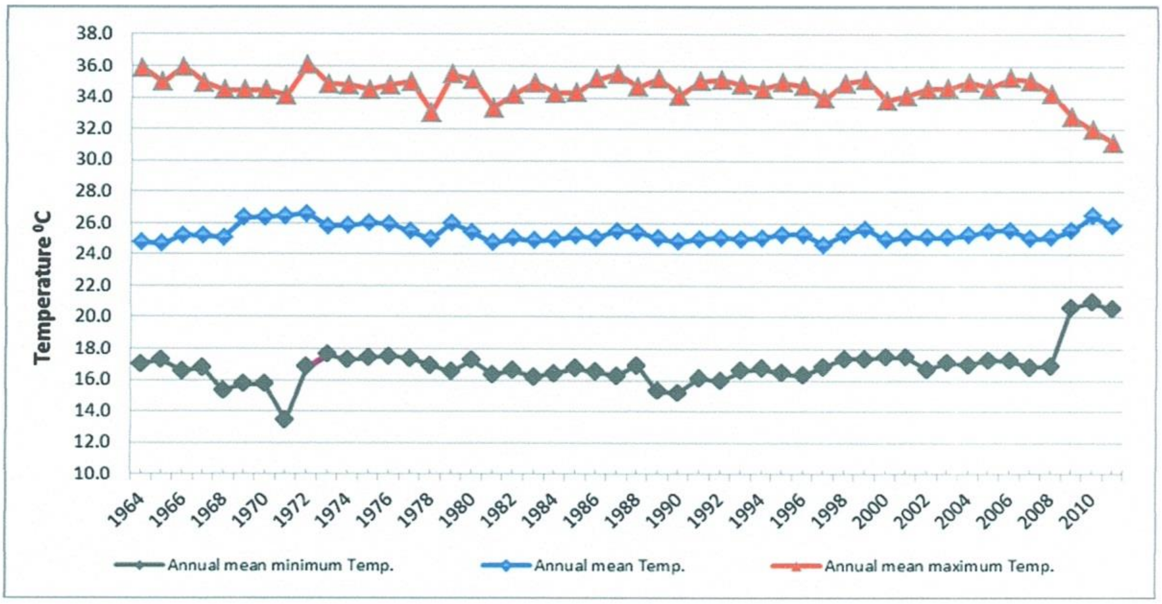


Figure 3.1 The annual mean minimum, mean and mean maximum temperatures in Rajshahi region during the period 1964-2011.

The long-term seasonal mean temperatures are also found to have increasing trend over the study period (1964-2011) (Figure 3.2) and Appendix-1-4. The highest average maximum temperature was 30.55^0C observed in the month of April in pro monsoon season and the lowest average temperature was 15.45^0C in the month of January in winter season.

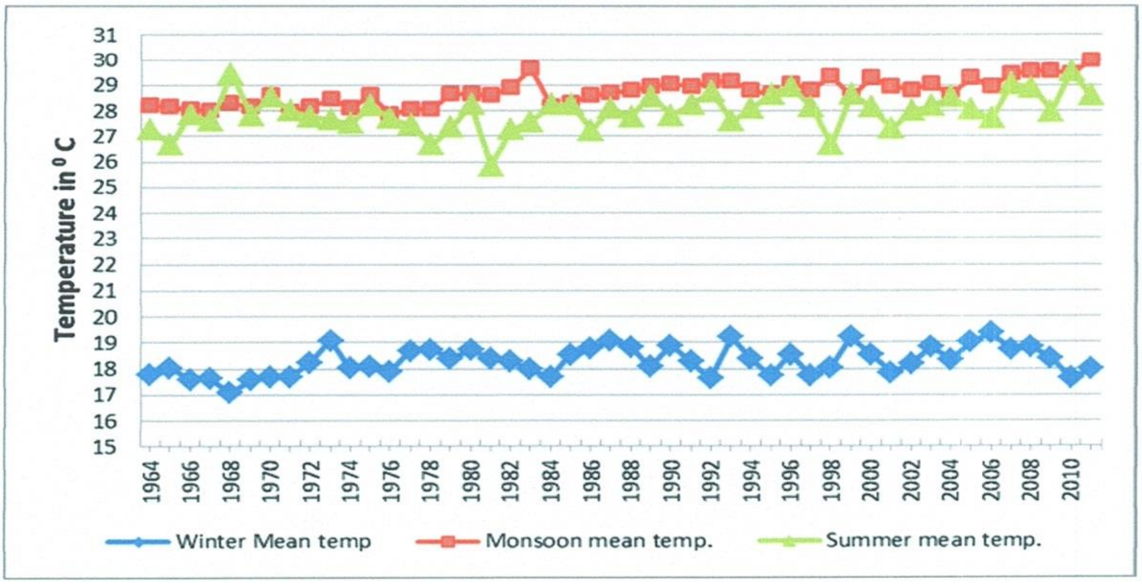


Figure 3.2 The annual winter mean, monsoon mean and summer mean temperatures in Rajshahi region during the period 1964-2011.

The figure 3.3, Appendix-3 indicates that the long-term monthly minimum temperature in the study area over the study period (1964-2011) was lowest in the month of January and December which corresponds to the coldest months observed in winter season of Bangladesh.

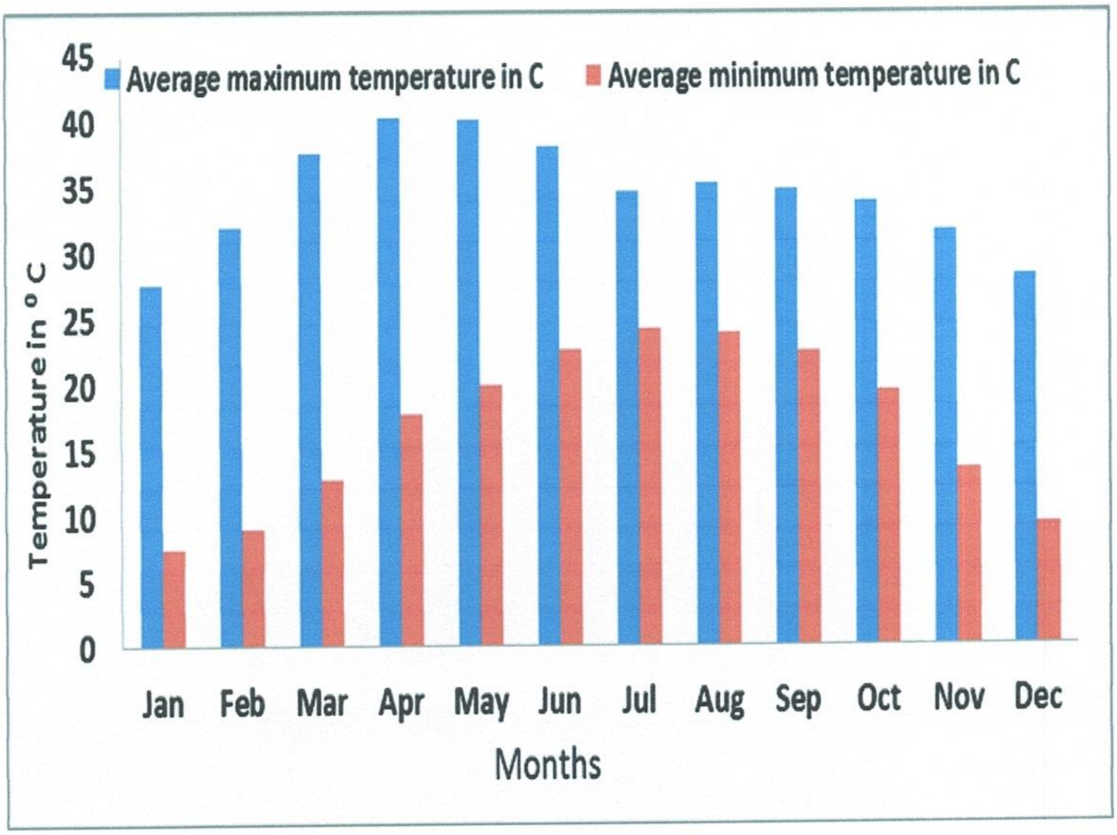


Figure 3.3 Monthly average maximum and minimum temperatures in Rajshahi region during the period 1964-2011.

The figure 3.3, Appendix-2 also shows that the long-term monthly maximum temperature in the study area over the study period (1964-2011) was highest in the month of April and May which corresponds to hottest months observed in summer/pre monsoon season of Bangladesh.

Trends in Rainfall in Study Area

The long-term changes in annual rainfall in the study area over the period (1968-2011) showed (Figure 3.4), Appendix-5 declining trends from last two decades. The average annual rainfall was 1489 mm/year.

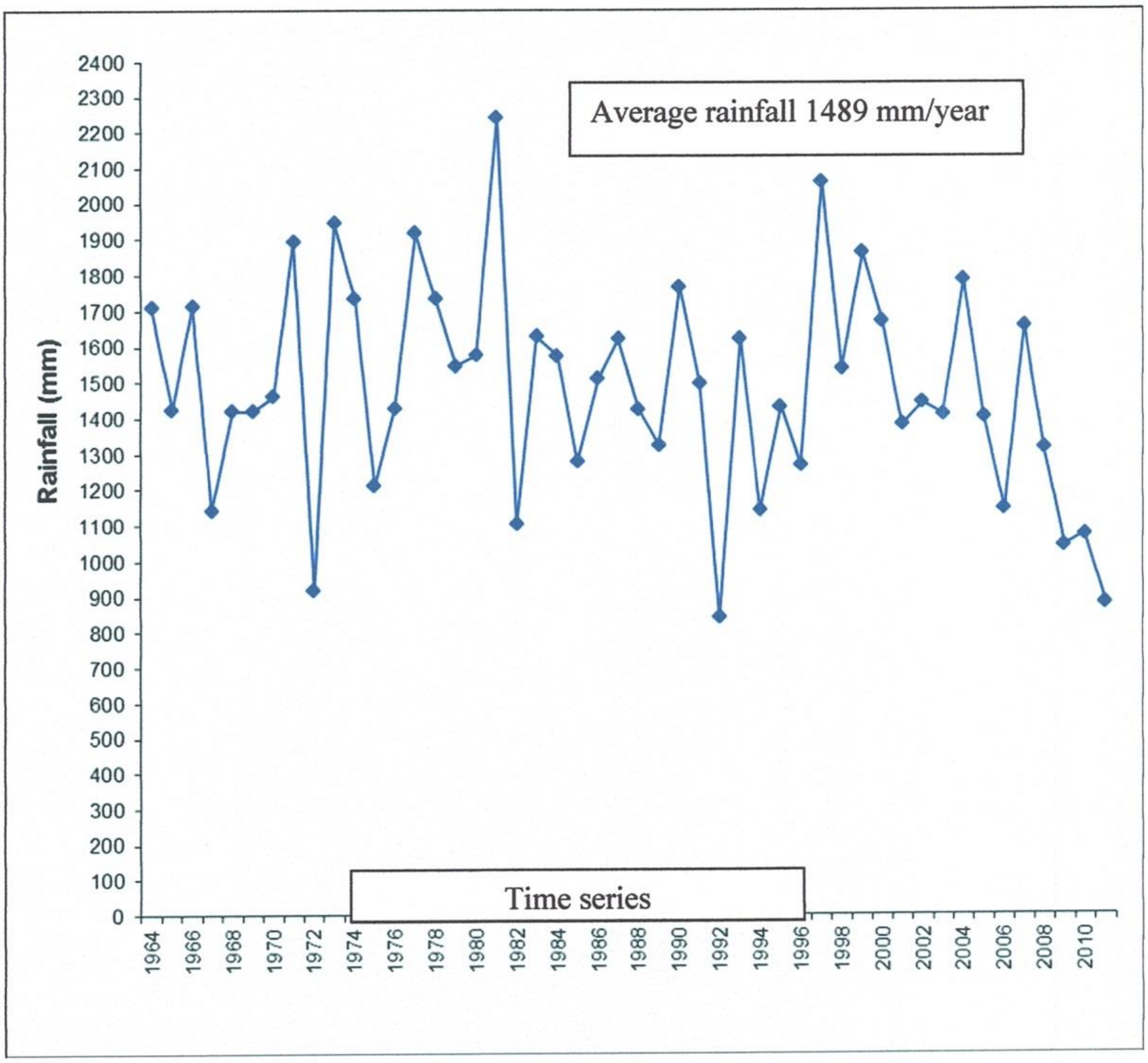


Figure 3.4 Annual average rainfall in Rajshahi during the year 1964-2011

The long-term seasonal rainfall in the study area (Figure 3.5), Appendix- 6 showing markedly reduced in winter and post autumn season. Most of the rainfall occurred in monsoon season that is also declined in the study area over the study period (1964-2011).

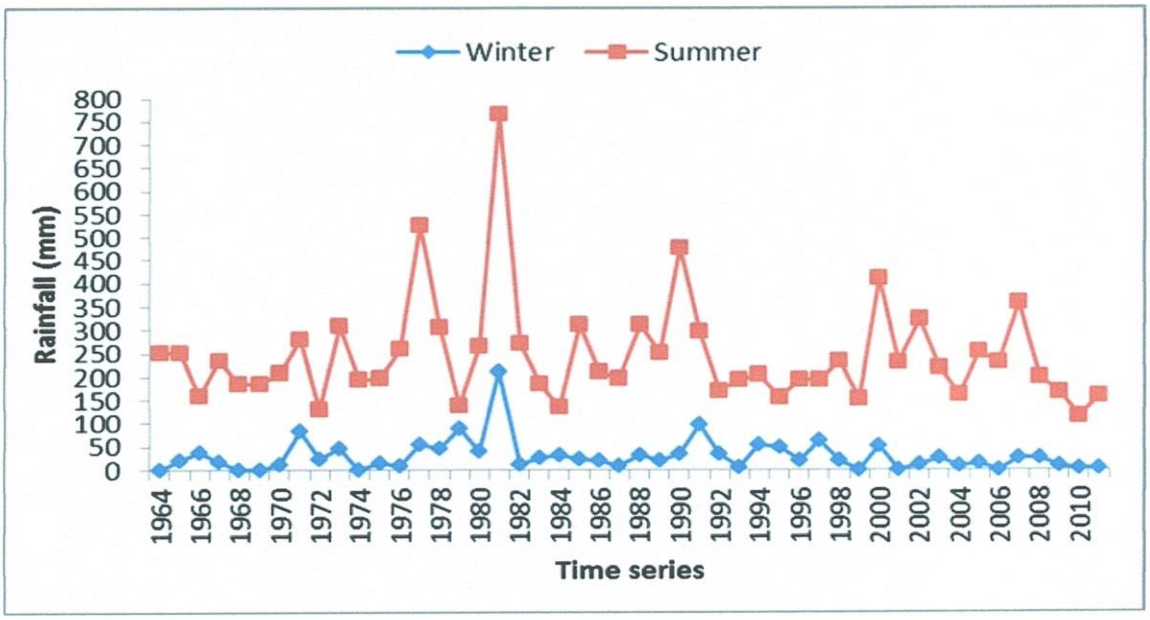


Figure 3.5 Annual winter and summer rainfall in Rajshahi during the year 1964-2011

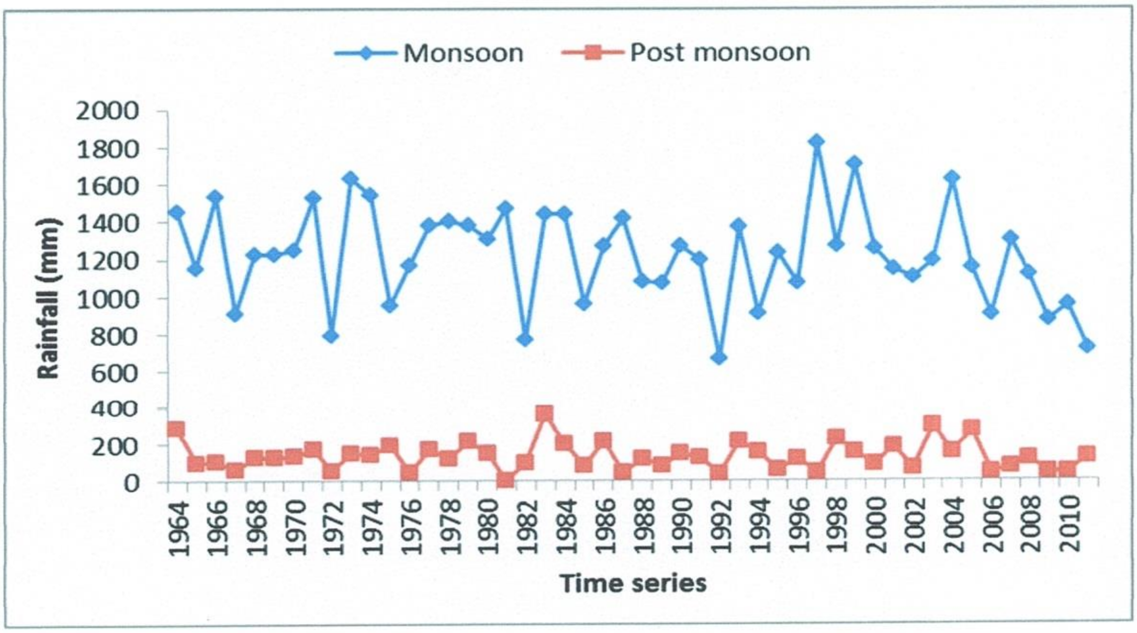


Figure 3.6 Annual monsoon and post monsoon rainfall in Rajshahi during the year 1964-2011

The average seasonal rainfall in the study area in the study period 1964-2011 during winter, summer, monsoon and post monsoon were 30.10 mm, 216.79 mm, 1222.37 mm and 131.56 mm respectively.

3.2 Climate Sensitive Infectious Disease Profile

Data/information of the major climate sensitive diseases were collected from 20 Upazilla Health Complex (UHC), 01 Municipality and 01 City Corporation health authorities, 02 Civil Surgeon's offices and also from MIS of DGHS, Dhaka office. It may be noted that data of diseases up to the year 2008 were collected from DGHS, Dhaka and later on (2009-2011) all the incidences of climate sensitive infectious diseases and their outbreak report were collected from all the Upazila Health Complex, Municipality, City Corporation, district Sadar Hospital and Civil Surgeon office by using specific weekly disease report format (appendix-ii).

In Bangladesh a good number of people suffer from diarrhoea, ARI, malaria, measles, kala azar, dengue and other infectious disorders. The following table and figures show the annual incidence of some of the major climate sensitive diseases and their trend in Bangladesh.

Table 4 Incidence of some major climate sensitive diseases in Bangladesh adapted from DG-Health bulletin 2012

SL	Disease	Incidence	Duration	Average incidence per year
1	Diarrhoea	28166084	Year 1999- 2011	2166521
2	Kala azar	1062 38	Year 1994- 2011	5902
3	Malaria	1534864	Year 1992- 2011	76743
4	Measles	136551	Year 1990- 2011	6502
5	Dengue	25413	Year 2000- 2011	2118
6	Nipah	197	Year 2001- 2011	18

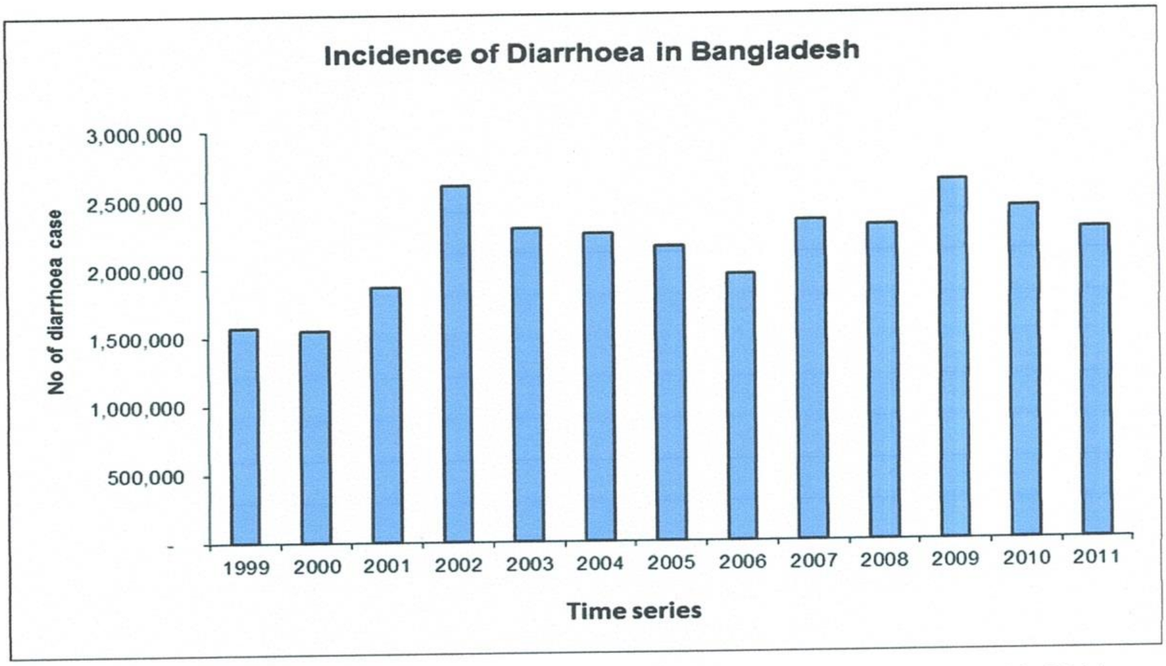


Figure 3.7: Incidence of diarrhoea in Bangladesh during the period of 1999-2011

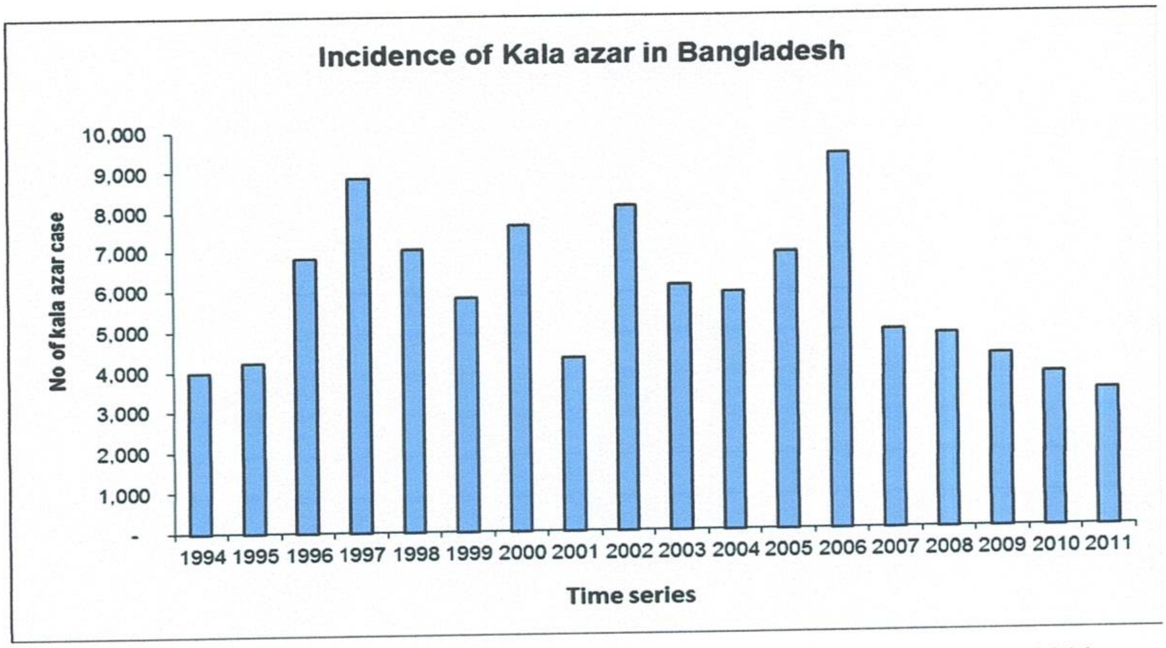


Figure 3.8 Incidence of Kala azar in Bangladesh during the period of 1994-2011

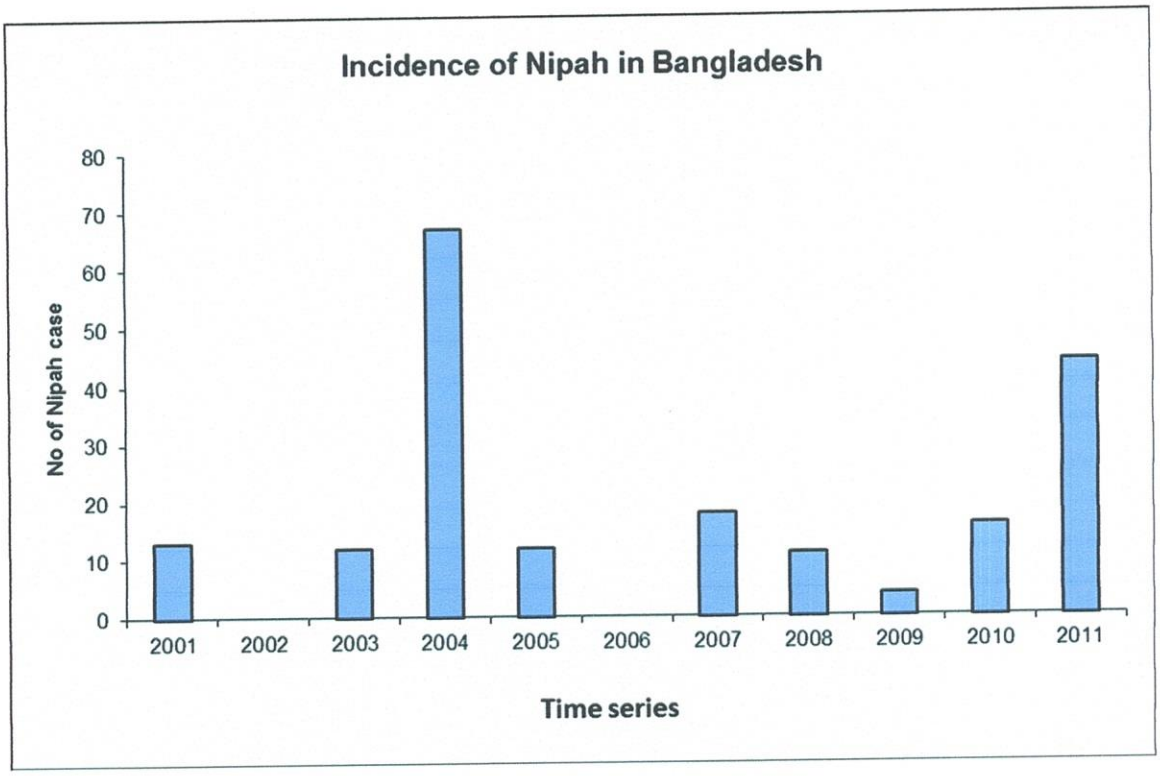


Figure 3.9 Incidence of Nipah in Bangladesh during the period of 2001-2011

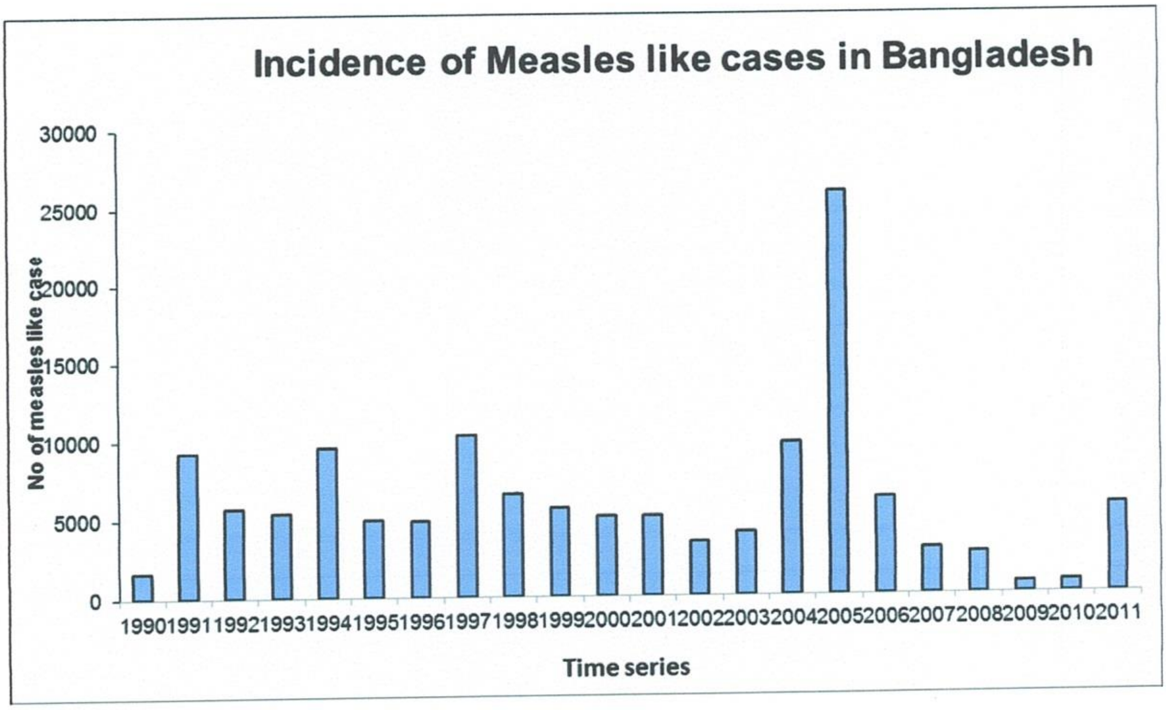


Figure 3.10 Incidence of Measles like cases in Bangladesh during the period of 1990-2011

Seasonal incidences of climate sensitive infectious diseases and their outbreak in each year over the study period were also observed. To explore the association between climate sensitive infectious diseases and climate factors correlation analysis was carried out using both secondary and primary data. Climate factors such as annual and seasonal rainfall, annual mean maximum and minimum temperature and climate sensitive diseases (*e.g.* Diarrhoea, Kala azar, Measles) were analyzed to find out the association between impacts of climate change on the outbreak of infectious diseases in the study area. Pearson's Coefficient method was applied to detect the extent of association between incidences of each disease and climatic factors. Data on climatic factors and incidences of climate sensitive infectious diseases from year 2000 to 2011 were used to find out the correlation.

A positive correlation implies that the greater the variation in the climatic factors the larger the number of incidences of diseases. The results of the correlation analysis between climatic factors and climate sensitive infectious diseases are individually shown below.

Diarrhoea

The Figure 3.12-3.14 and table-3.2 show that the incidences of diarrhea have positive correlation with annual and seasonal rainfall and with both mean maximum and minimum temperature. The highest number of diarrhoea cases (39092 cases) and highest rainfall (1786 mm) was reported from the study area in the year 2004.

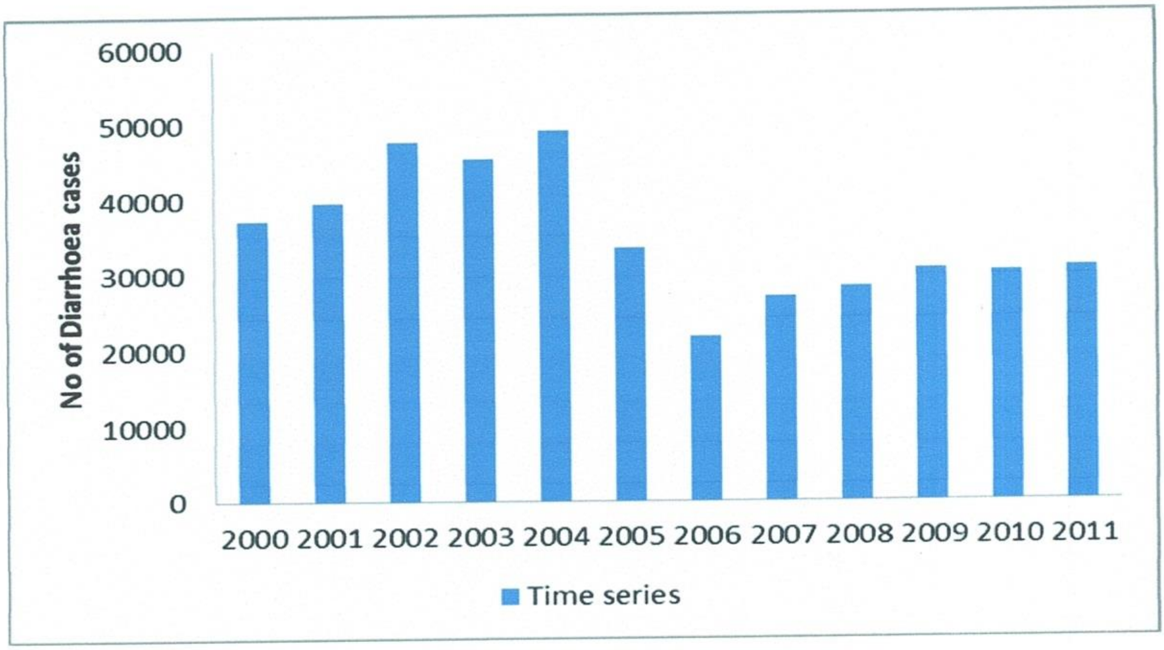


Figure 3.11 Annual incidence of diarrhoea in the study area during the period of 2000 to 2011

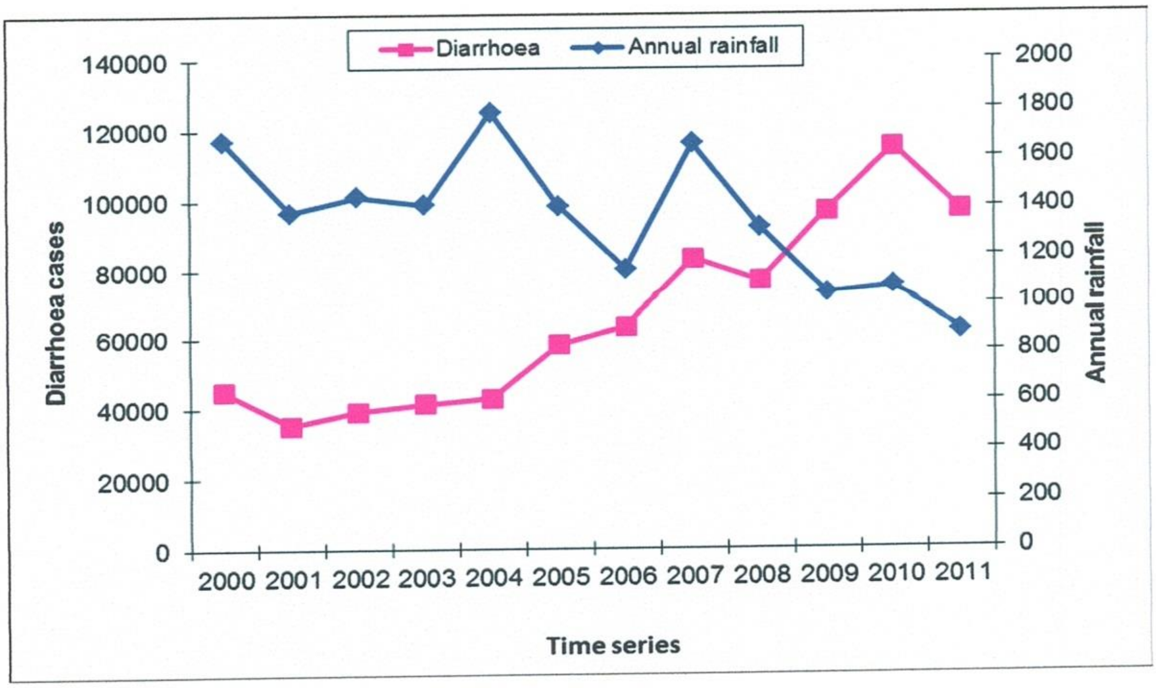


Figure 3.12 Trends of annual rainfall and diarrhoea incidences in the study area during the period of 2000 to 2011

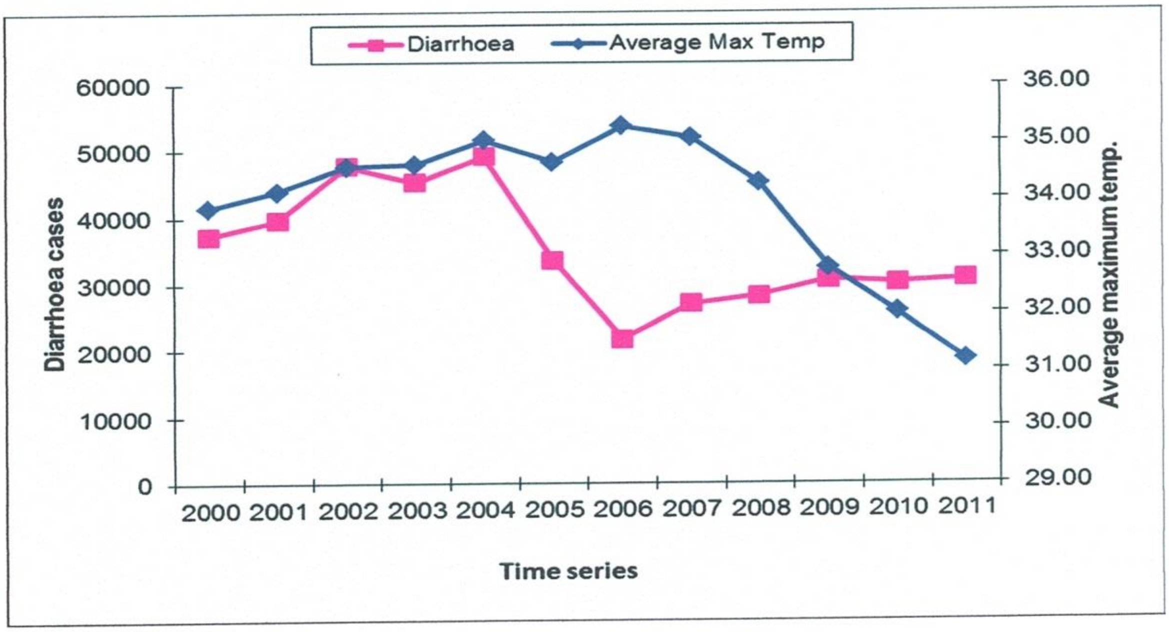


Figure 3.13 Trend of annual average maximum temperature and diarrhoea incidences in the study area during the period of 2000 to 2011

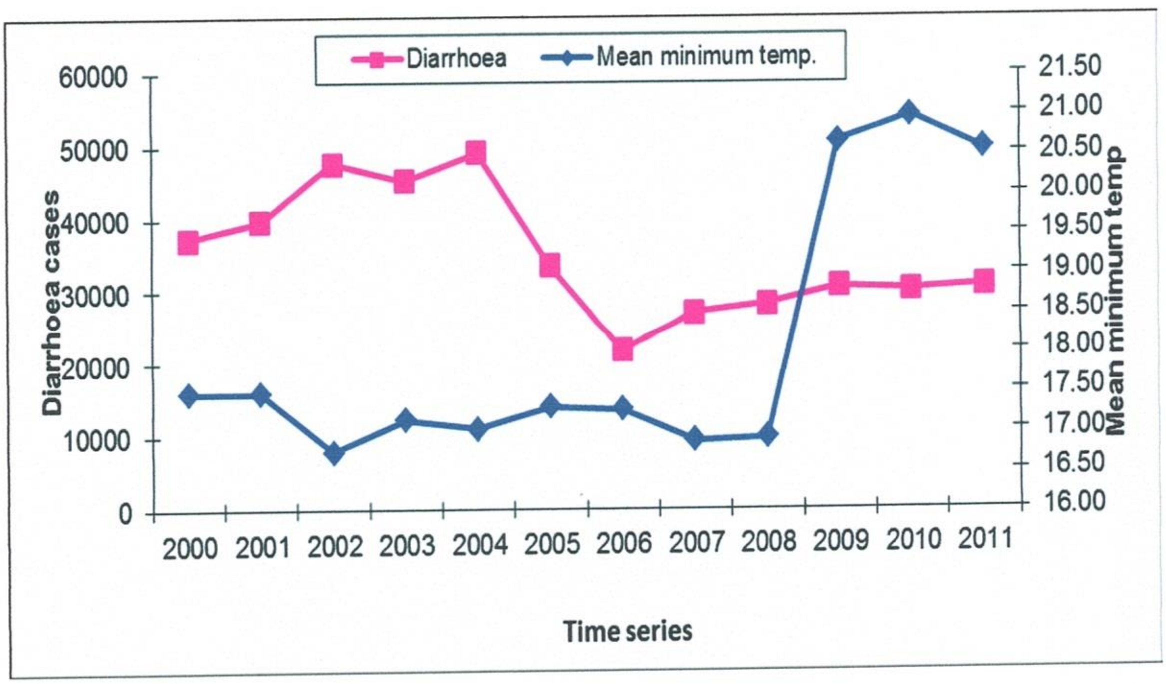


Figure 3.14 Trend of annual average minimum temperature and diarrhoea incidence in Study area during the period of 2000 to 2011

Table 5 Values of Correlation coefficient of climatic variables and diarrhoea in study area during the study period (2000-2011)

Correlation on incidence of Diarrhoea and climatic factors			
Sl. No	**Climatic variables (Year 2000-2011)**	**Disease**	**Value of Correlation coefficient**
A	Total annual rainfall	Diarrhoea	+0.016
B	**Total seasonal rainfall**		
1	Winter (Dec, Jan, Feb)	Diarrhoea	+0.193
2	Summer or Pre-monsoon (March, April, May)	Diarrhoea	+0.065
3	Monsoon (June, Jul, Aug, Sept)	Diarrhoea	+0.132
4	Autumn or Post monsoon (Oct, Nov)	Diarrhoea	+0.060
C	Annual average maximum temperature	Diarrhoea	+0.014
D	Annual average minimum temperature	Diarrhoea	+0.002

From above table incidences of diarrhea were found to have positive correlation (+0.016) with total annual rainfall and total winter (+0.193), summer (+0.065), monsoon (+0.0132) and total post monsoon (+0.060) seasonal rainfall over the reported period. Occurrence of diarrhea remained highest during monsoon in most of the year. The highest correlation found with total seasonal winter rainfall (+0.193) and lowest with annual average minimum temperature (+0.002) in the study area.

Kala-azar/Leishmaniasis

Kala-azar incidences, climatic factors (rainfall and temperature), vectors breeding sites were collected from the study districts. Relationship between kala-azar patient and their distribution were evaluated. Figure- 3.15, 3.16 and appendix tables-8 show the yearly and seasonal incidences of kala-azar in the study areas. The incidences of kala-azar found highest in monsoon season in the month of July, August, October and November and declined in winter months of December, January and February.

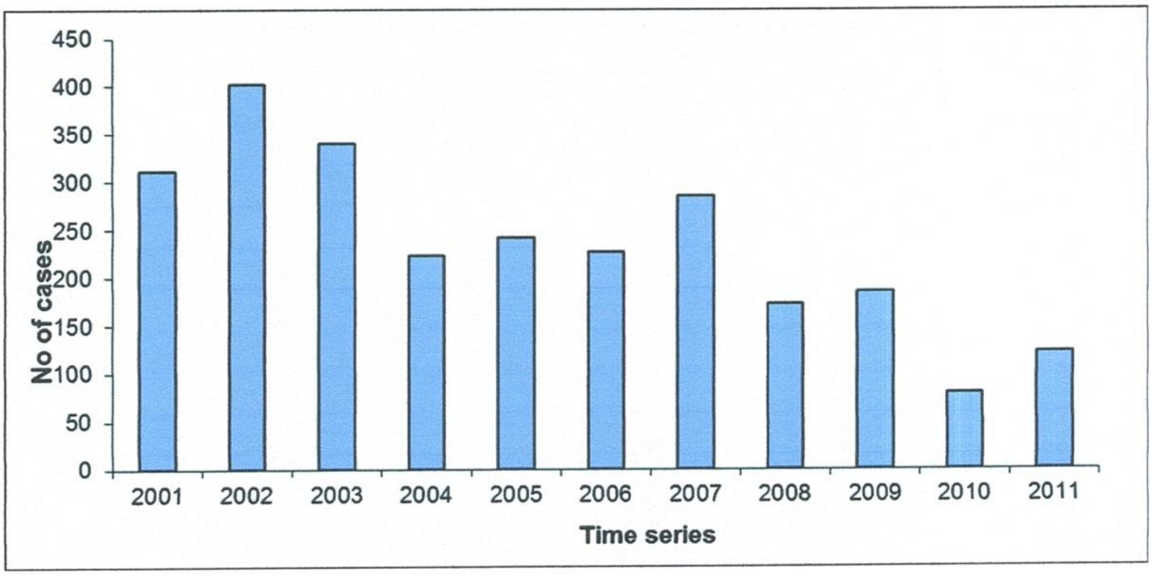


Figure 3.15 Incidence of Kala-azar in study area during the period of 2001 to 2011

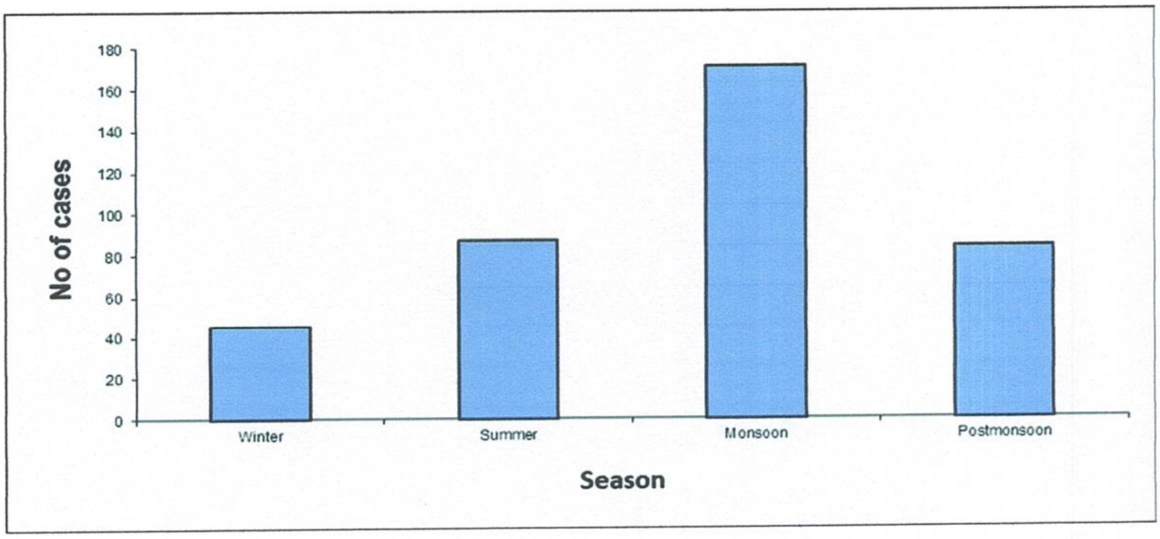


Figure 3.16 Seasonal incidence of Kala-azar in study area during the period of 2001 to 2011

Pearson's correlation was calculated for the number of kala-azar patients of each season with annual and seasonal rainfall and with average maximum and minimum temperature. Kala-azar was found (Table-3.3) to have positive correlations with both annual and seasonal rainfall and annual average maximum temperature. In winter there were significant positive impacts of rainfall with the increased number of kala-azar patient. Negative correlation also found between kala-azar and annual average minimum temperature in the study period.

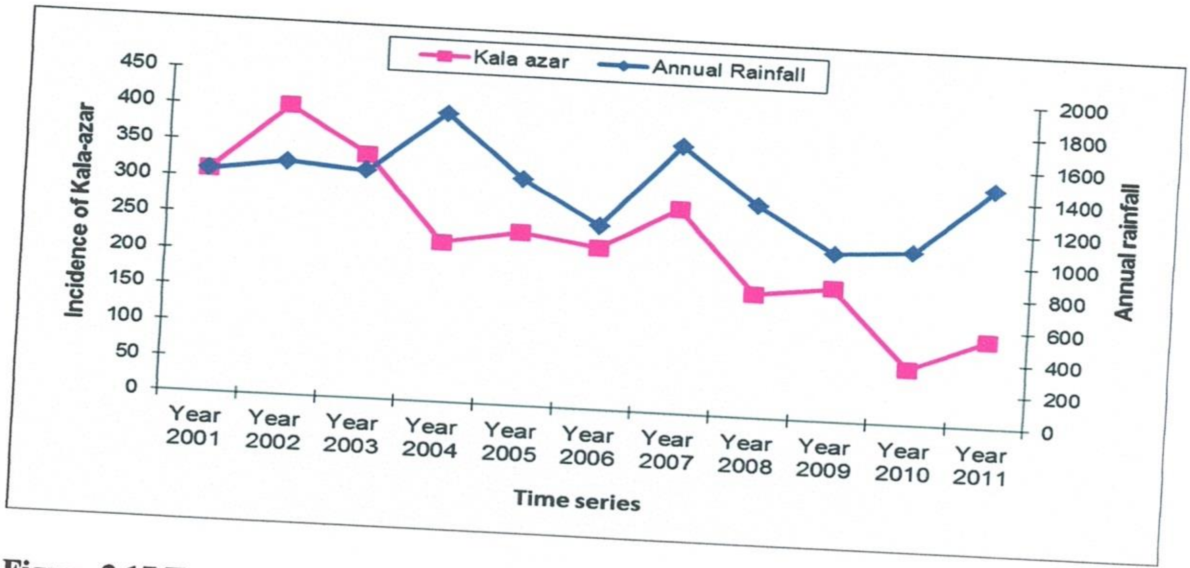


Figure 3.17 Trend of annual rainfall and Kala-azar incidences in the study area during the period of 2001 to 2011

Table 6 Values of Correlation coefficient of climatic variables and Kala azar in study area during the study period (2000-2011)

Correlation on incidence of Kala azar and climatic factors			
Sl. No	**Climatic variables**	**Disease**	**Value of Correlation coefficient**
A	Total annual rainfall	Kala azar	+0.498
B	**Total seasonal rainfall**		
1	Winter (Dec, Jan, Feb)	Kala azar	+0.937
2	Summer or Pre-monsoon (March, April, May)	Kala azar	+0.715
3	Monsoon (June, Jul, Aug, Sept)	Kala azar	+0.998
4	Autumn or Post monsoon (Oct, Nov)	Kala azar	+0.567
C	Annual average maximum temperature	Kala azar	+0.609
D	Annual average minimum temperature	Kala azar	-0.635

Table-3.3 and Figure 3.18 and 3.19 showed that kala-azar have positive correlation with both annual and seassonal rainfall.The highest correlation (+0.998) of kala-azar incidence was observed with total monsoon rainfall, then dry winter rainfall (+0.937) and lowest (+0.567) at post monsoon rainfall.

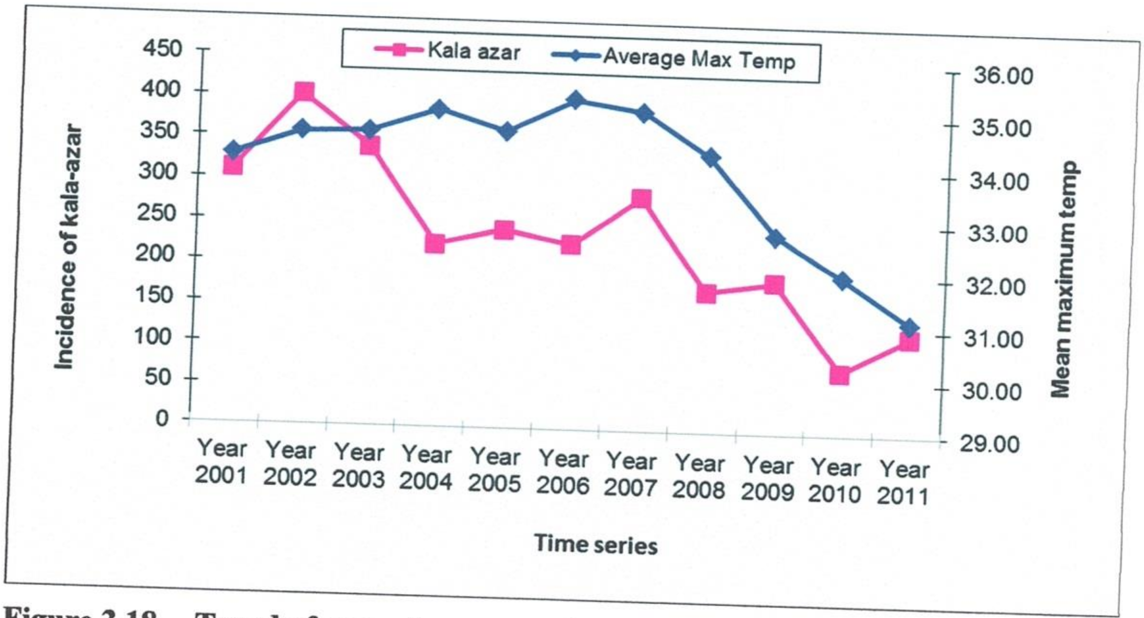


Figure 3.18 Trend of annual mean maximum temperature and Kala-azar incidences in the study area during the period of 2001 to 2011

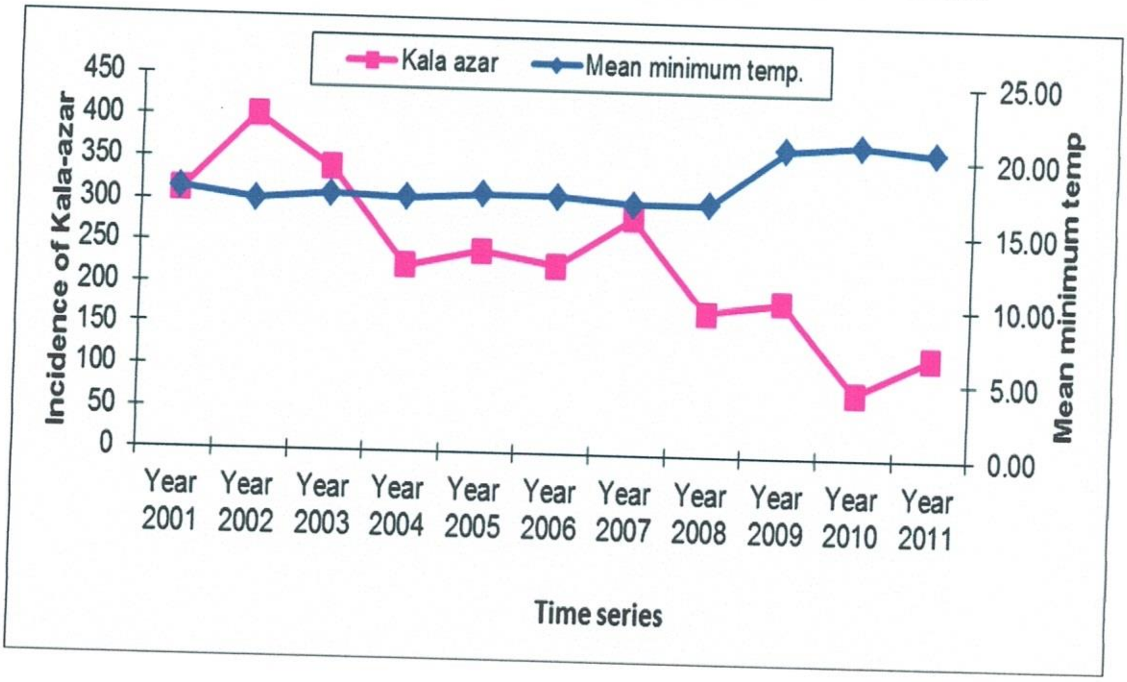


Figure 3.19 Trend of annual mean minimum temperature and Kala-azar incidences in the study area during the period of 2001 to 2011

The incidence of kala-azar and climate factors for the period of 2001-2011 represented in Figure-3.18 and 3.19 have positive correlation (+0.627) with annual mean maximum temperature and negative correlation (-0.68) with annual mean minimum temperature.

The present data showed significant co-relationship between climatic factors and kala-azar incidences in study area.

Measles

Figure 3.20 shows most of the outbreak occurred in March, April and May, whereas number of cases highest in April, May and June. These 4 months corresponds to the summer season of Bangladesh. Measles were found (Table-3.4) to have positive correlation with both seasonal rainfall and annual average maximum temperature and negative correlation with annual rainfall. In winter there were significant positive impacts of rainfall with the increased number of patient. Negative correlation also found between measles like diseases and annual average minimum temperature in the study period.

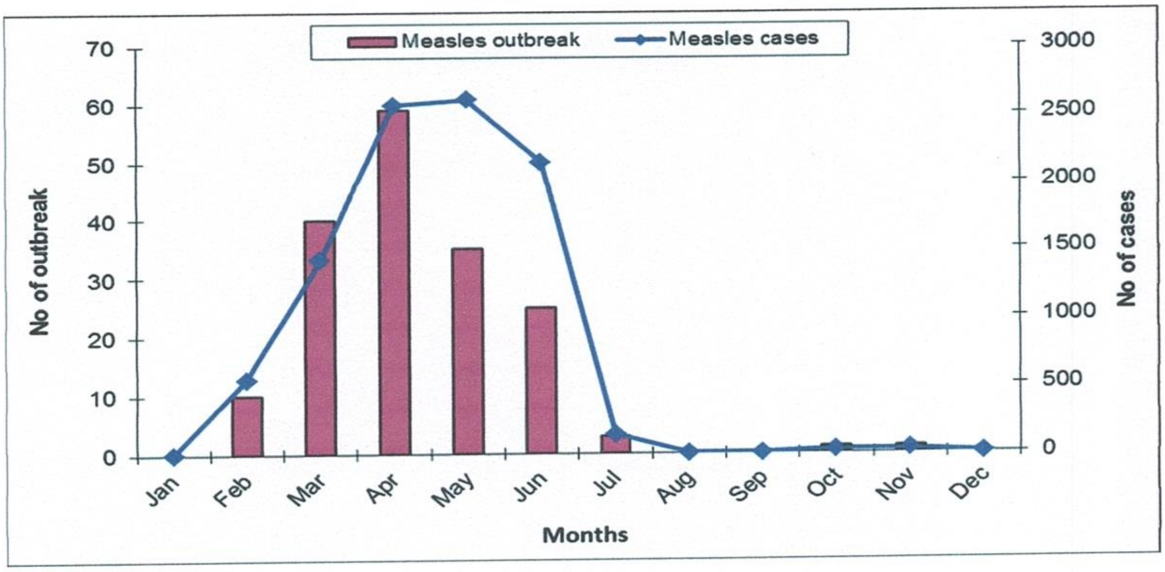


Figure 3.20 Incidence of Measles outbreak and cases in study area during the study period

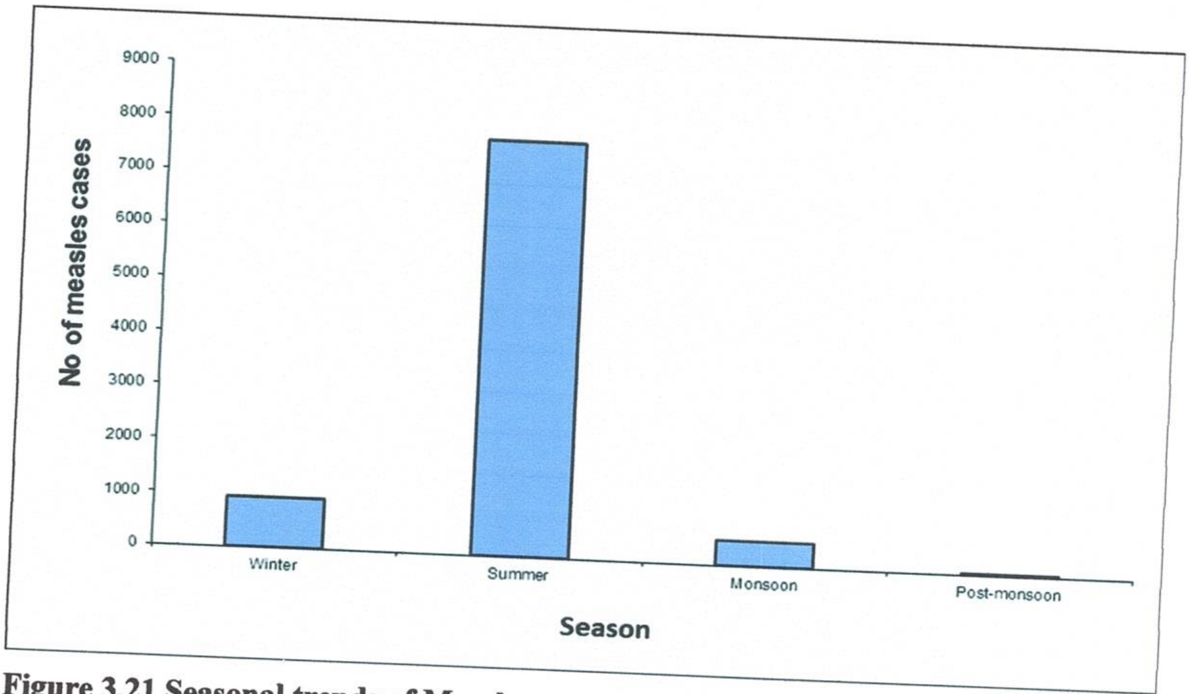


Figure 3.21 Seasonal trends of Measles cases in study area during the study period

Table 7 Values of Correlation coefficient of climatic variables and Measles in study area during the study period (2000-2011)

Correlation on incidence of Measles and climate factors			
Sl. No	**Climate variables**	**Disease**	**Value of Correlation coefficient**
A	Total annual rainfall (N=12)	Measles	-0.475
B	**Total seasonal rainfall (N=12)**		
1	Winter (Dec, Jan, Feb)	Measles	+0.899
2	Summer or Pre-monsoon (March, April, May)	Measles	+0.233
3	Monsoon (June, Jul, Aug, Sept)	Measles	-0.131
4	Autumn or Post monsoon (Oct, Nov)	Measles	+0.1000
C	Annual average maximum temperature (N=12)	Measles	+0.967
D	Annual average minimum temperature (N=12)	Measles	-0.003

The incidences of measles like cases were found to have positive correlation with annual average maximum temperature (+0.967) and seasonal winter (+0.0899), summer and post monsoon (+0.1000) rainfall. Negative correlation were found with total annual rainfall (-0.0475), seasonal monsoon rainfall (-0.131) and annual average minimum temperature (-0.003).

3.3 Results from Primary Data

This section deals with findings of 60 cluster sample using 30 cluster survey technique in two study districts and all reported infectious disease outbreak in the study period. In each cluster 7 household's respondent were included. The sample survey included a total of 420 households. Some demographic information and vaccination status of less than 5 years children were also recorded during house to house survey. The findings of the study have been assessed quantitatively and qualitatively to find correlation between impact of climate change and outbreak of infectious diseases among children.

3.3.1 Socio-Demographic Profile of the Study Area

The socio-demographic status of households in the study area has been recorded. The demographic factors of the households covered in the study area include age, sex, education of the respondents (child's mother), profession, health etc. The variables have been described in the following sub-sections:

Household Size and Sex Ratio in the Study Area

The cluster household survey of study area revealed that the average household size (the number of person per household) was 5.1. The male members of households were slightly higher than female. Male constituted 51.9 percent of household members while 48.1 percent were female (Figure 3.22). However, the survey revealed that the total number of members of households varied from cluster to cluster unit.

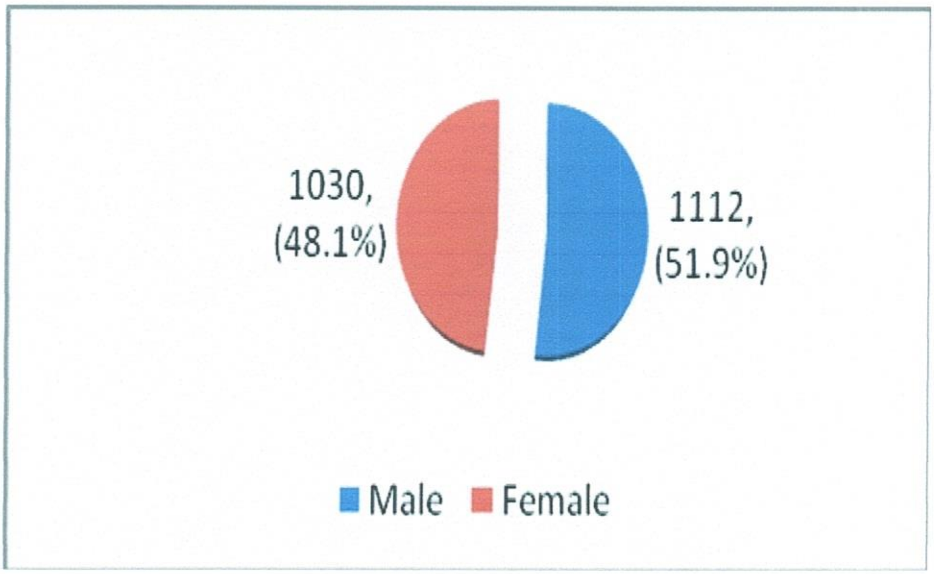


Figure 3.22 Distribution of household members by sex in study area

Household Members by Age Group

It was found that the age of maximum number of household members (51.4%) of study area ranged between 16-60 years (Figure-3.23). The second highest category of the study households were between 5-15 years (18.3%), while 10.7% population were more than 60 years, 4.8% was under 1 year and 14.8% between 1-4 years. As the study was designed to survey those households which have at least one child within 5 years old, so the age group of the study area may not reflect the normal age group scenario.

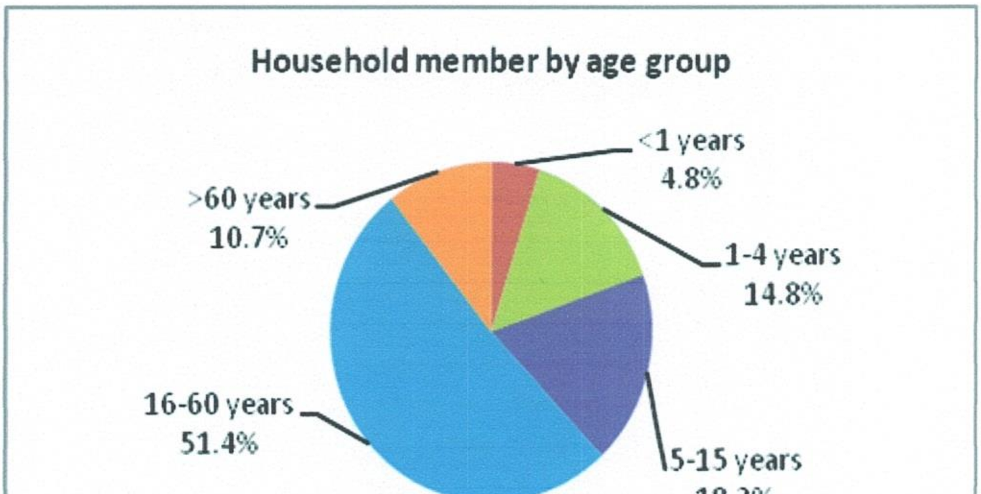


Figure 3.23 Percent distribution of household member by age group in study area

Education of Respondent Mother

It was found that 71% of respondent's mother finished primary education, 2% were illiterate while 19% passed SSC and 6% passed HSC level. The rest 2 percent of the respondent mothers having graduate and higher degrees (Figure 3.24).

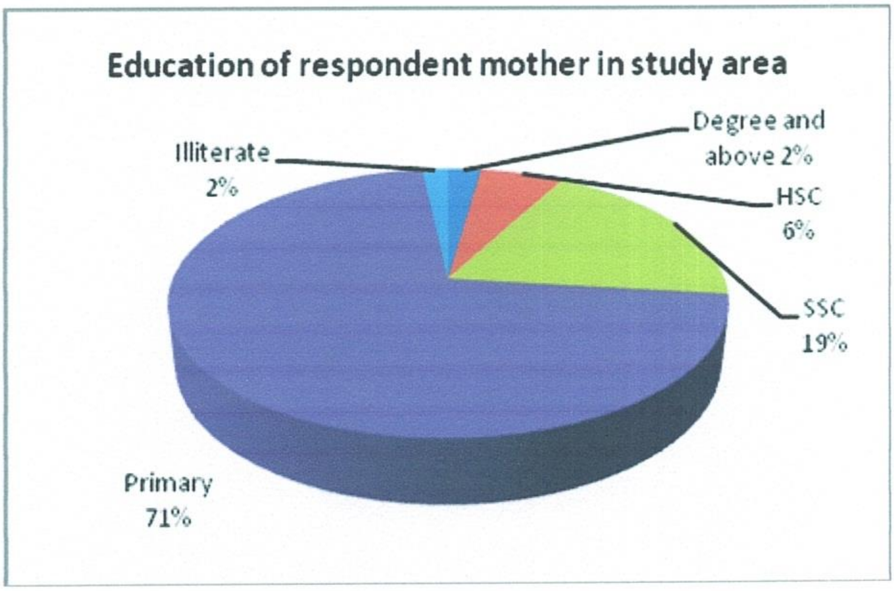


Figure 3.24 Percent distribution of respondent mother by education in Study Area

3.3.2 Common Infectious Diseases in the Study Area

The common infectious diseases which affected the household members especially children are diarrhoea, common cold/cough/fever, measles like disease (locally known as Kheshra/Koda), skin disease, kala-azar, jaundice. Although the household respondents identified various diseases in the study area but here the analyses mainly focused on climate sensitive disease among children. According to response of households (Figure-3.25, Appendix-9), diarrhoea was identified as common disease among children as mentioned by 86 percent respondents in the study area while 7 percent of the respondent mother mentioned about measles like disease, jaundice 6 percent and kala-azar 1 percent. On the other hand, most of the respondents of the entire survey unit identified cough/cold/fever as a common infectious disease among children.

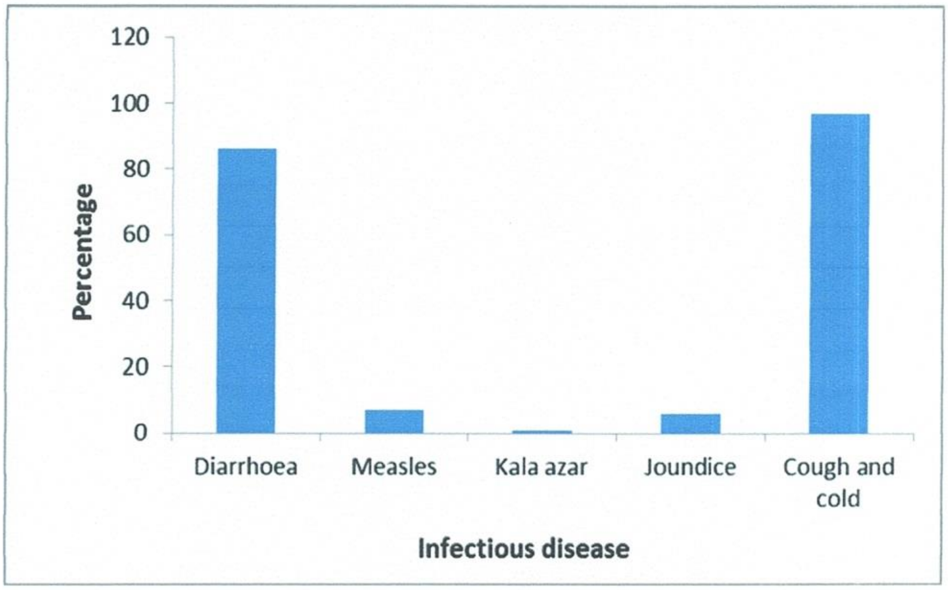


Figure 3.25 Incidences of Infectious Diseases among Children in Study Area

3.3.3 Respondents' Opinion on Possible Reasons for Disease Incidence

The respondent responses regarding the major factors influencing infectious diseases in the study area were analyzed and it was found that most of the childhood infectious diseases like diarrhoea, measles like disease, common cold, cough, fever and kala-azar have association with climatic variables. According to the opinion of respondents' of all cluster samples, temperature variation was responsible for most of the diseases incidence and other significant reasons include rainfall variation, water pollution and natural disaster. With regard to reasons of diarrhoeal incidences, 44% are attributable to change in temperature, followed by 29% to rainfall variation, 13% to water pollution and 8% to natural hazards. Most (74%) of the respondent mentioned temperature variation as factor of measles like disease. While 3%, 8% and 4% respondents mentioned rainfall variation, natural hazards and other factors as causes respectively. Among the respondents, 41%, 33%, 3%, 3% and 14% respectively mentioned that temperature, rainfall, natural hazards, water pollution and others (poor sanitation and housing) were the factors responsible for kala azar. (Figure 3.26-3.28, Appendix-9)

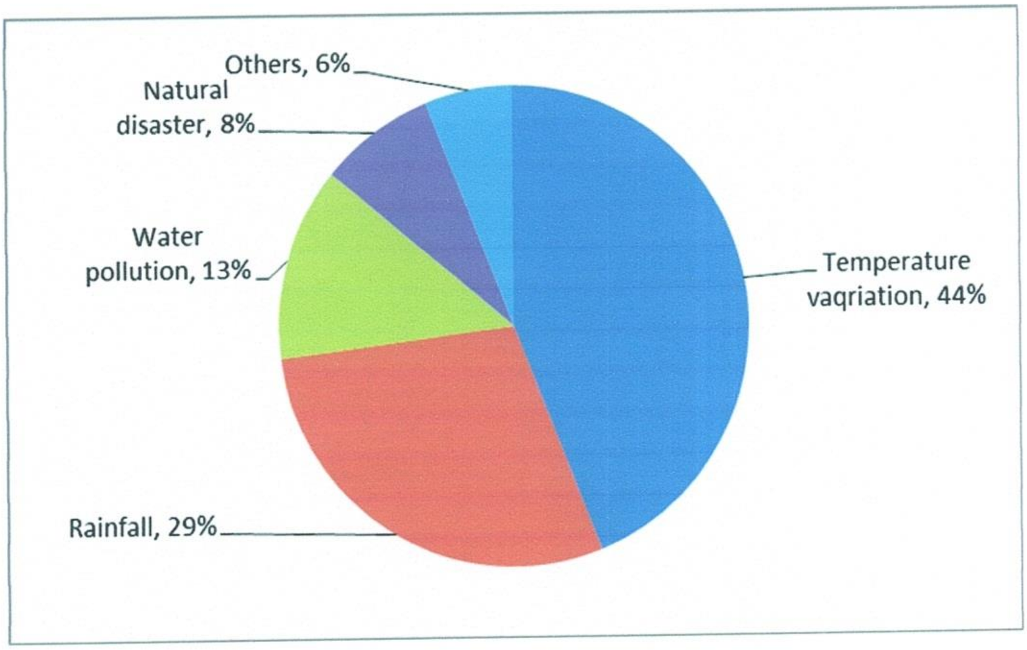


Figure 3.26 Factors responsible for diarrhoea according to percent respondent's opinion in the study area

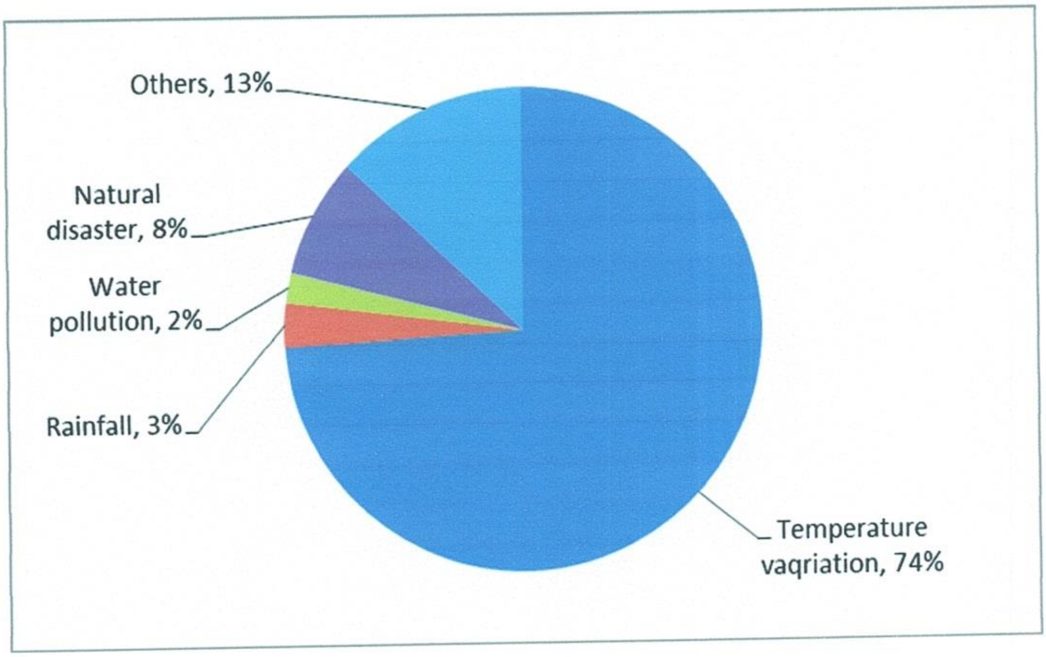


Figure 3.27 Factors responsible for measles according to percent respondents Opinion in the study area

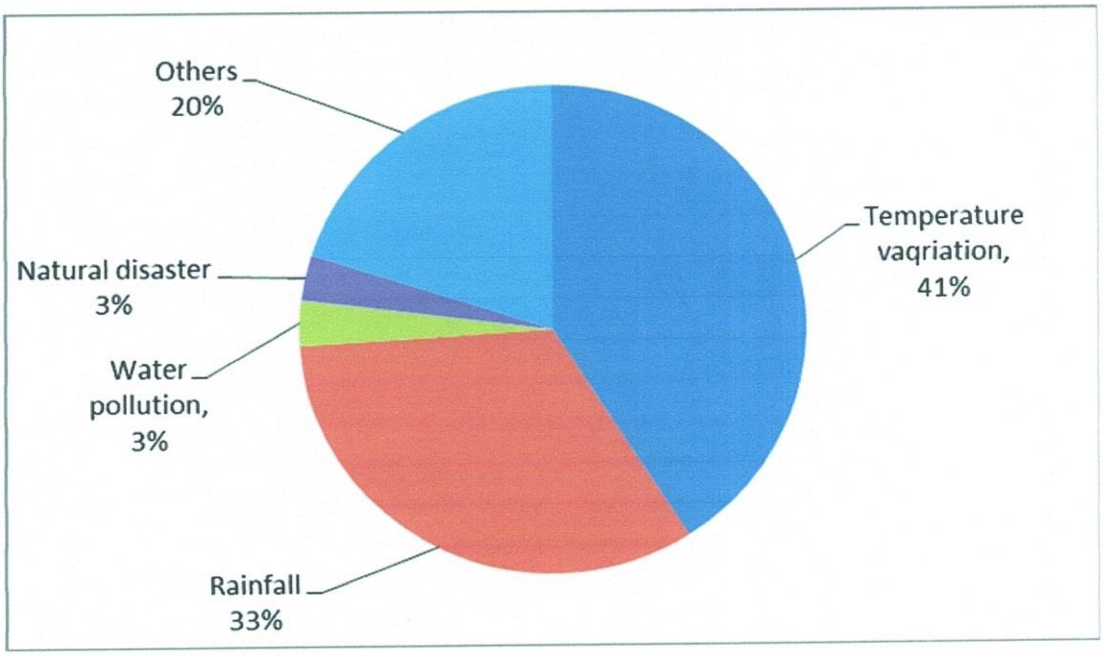


Figure 3.28 Factors responsible for Kala-azar according to percent respondents Opinion in the study area

3.3.4 Incidence of Infectious Diseases over last 10 years

Regarding incidence of infectious diseases in last 10 years, most of the respondents mentioned about highest incidence of diarrhea (81%) and ARI/cough and cold (87%) while 11% and 1% respondents observed measles like disease and kala-azar respectively which affected their family members in last 10 years. Among 420 respondents, only one respondent in the study area mentioned about Nipah virus infection that affected one of their family member in last 10 years.

3.3.5 Respondents' Knowledge and Understanding on Climate Change

Understanding on the term "climate change" among the respondents of the households in the study area was not very satisfactory. The findings show that only 17 percent of the respondents could appropriately understand the climate change phenomenon. However, most of the respondents have the clear cut ideas about season of Bangladesh.

3.3.6 Prevention and Control of Vaccine Preventable Diseases and Vaccination Status of Children in the Study Area

To assess the vaccination status of children in the study area, only valid vaccination coverage was assessed. Valid coverage was assessed in terms of valid doses of any antigen administered to a child of one year age. A valid dose was a recommended dose of a recommended antigen administered in a recommended age and or intervals. For the protection of children, government of Bangladesh introduced routine immunization against deadly infectious diseases of children, namely childhood tuberculosis, diphtheria, pertusis, tetanus, hepatitis-B, hemophylus influenza type B (HiB), polio and measles. WHO recommends that each child be immunized with one dose of BCG against tuberculosis, three dose of penta against diphtheria, pertusis, tetanus, hepatitis- B and HiB, 4 dose of polio against poliomyelitis and one dose of measles vaccine against measles. It also recommends that all the antigen be administered to the child by the first birthday according to the following schedule: BCG at or after birth; Penta1/OPV1 at the age of six weeks or after; Measles vaccine at the age of 38 weeks or after. The interval between the consecutive doses of Penta/OPV should be four weeks (28 days) or more meaning that Penta2/OPV2 should be given four weeks (28 days) or more after Penta1/OPV1 and Penta3/OPV3 should be given four weeks (28 days) or more after Penta2/OPV2. Considering the above schedule vaccination data were collected, collate and found almost all (100%) the children got access to vaccination service. Data showed BCG coverage was 100 percent while penta1, penta2, penta3 and measles coverage were 99 percent, 96.60 percent, 92.40 percent and 86.20 percent respectively (Figure 3.29).

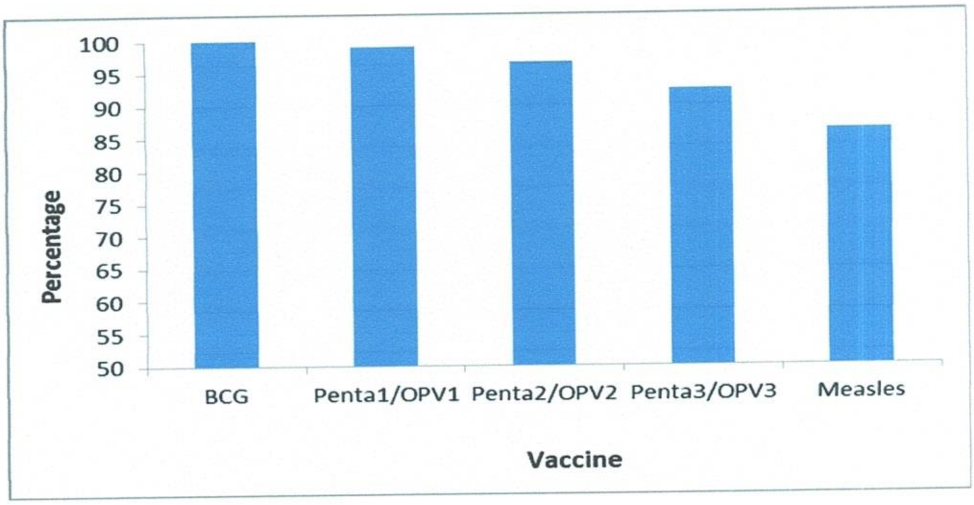


Figure 3.29 Vaccination status (%) of children bellow one year of age in the study area

3.3.7 Incidence of Vaccine Preventable Diseases in Study Area over the Study Period

It was found that there was no report of childhood tuberculosis, diphtheria, poliomyelitis and pertusis in the study area within the study period (primary data collection period) while 4 neonatal tetanus cases, one in year 2009, two in year 2010 and one in 2011 were reported (Table-3.5). The incidence rate of neonatal tetanus (NT) in the study area was 0.012/1000 live birth per year that is neonatal tetanus incidence rate met national target (national target is 1 or more/1000 live birth).

Table 8 Vaccine Preventable Diseases in the Study Area

Diseases	Year 2009	Year 2010	Year 2011	Total
<5 Tuberculosis	-	-	-	-
Diphtheria	-	-	-	-
Pertusis	-	-	-	-
Neonatal Tetanus	1	2	1	4
Poliomyelitis	-	-	-	-
Measles	78	54	104	236

Note: (-) not found

Chapter Four
Discussion

Incidences of infectious diseases in human not only influenced by climatic factors but also depend on nutritional status, immunization status, socio-economic and educational status of the individuals, family and community. Under this study health impacts due to climate change, climate variability issues and their correlation were assessed by both primary and secondary data/information. The primary data on family size, socio economic condition, vaccination status of children and the community perceptions regarding the climatic change and infectious diseases were generated through face to face interview and cluster survey.

The survey shows that the average household size was 5.1, consisting of 51.9% male and 48.1% female population in the study area. Majority 51.4% of the household members ranged between 16-60 years age group whereas 18.3% within 5-15 years and 19.6% under 5 years age group. These statistics is consistent with BBS report 2009.

Though the study shows the knowledge of respondents regarding climate change was not very satisfactory but most of them have clear cut ideas about the season of Bangladesh and seasonal association with infectious diseases.

The climate factors like temperature and precipitation were considered as the key determinants of the distribution of many infectious disease carrying vectors. Water borne (e.g. diarrhoea, hepatitis A and E), air borne (e.g. ARI, measles, mumps, rubella) and vector borne (e.g. malaria, kal-azar, dengue) diseases are climate sensitive. Nipah virus infection, Chikungunia and Japanese encephalitis are

3.3.8 In-depth Investigation of Reported Outbreak in the Study Area

During in-depth investigation of reported outbreak a prescribed line listing form was used (Appendix-iii, iv) and interviewed diseased person about the course of disease and their link with climatic variables. Regarding climatic variables, most of the respondent's mentioned that there is change in seasonal temperature, rainfall, humidity etc. Many of the respondents specially said that the lengths of summer and winter have been changed nowadays in comparison to the past. Average temperature is felt to be increasing in both summer and winter months in the study area. The length of winter shortened and came late in comparison to the past. Almost all the respondents gave opinion on temperature and rainfall variations.

A lot of information on course of disease were gathered from the measles like outbreak areas. In response to first reported cases (index case) from Upazila Health Complex, Sadar Hospital and NGO clinic, a quick investigation performed to confirm the clinical diagnosis and blood sample collected for serological study. By tracking index cases (236 cases) in the community a total of 174 measles like outbreak was identified and clinically confirmed by case investigation and community searching with a prescribed outbreak investigation format during the study period (year 2009-2011) within the study area. From each outbreak site blood sample were collected from the clinically confirmed suspected measles like cases and serological study was conducted to identify the Immunoglobulin M (IgM) for measles and Immunoglobulin M (IgM) for rubella. On the basis of laboratory report measles like outbreak were classified as;

(a) Confirmed measles outbreak- at least 2 sample measles IgM positive;

(b) Confirmed rubella outbreak- at least 2 sample rubella IgM positive;

(c) Mixed measles rubella outbreak- at least one measles and one rubella IgM positive; and

(d) Discard outbreak- all sample negative for both measles and rubella. Laboratory report of Measles like outbreak investigation data revealed (Table-3.6) that out of 174 outbreaks, 11 were laboratory confirmed measles outbreak consisting of 491 cases, 126 laboratory confirmed rubella outbreak consisting of 8042 cases, 25 mixed measles and rubella outbreak consisting of 191 cases and 12 discarded as non-measles non rubella outbreak consisting of 456 case.

Table 9 Measles like Outbreak and Cases in the Study Area

Year	Lab confirmed Measles		Lab confirmed Rubella		Mixed measles & rubella		Discarded outbreak	
	No of OB	No of case	No of OB	No of case	No of OB	No of case	No of OB	No of case
2009	0	0	55	5338	0	0	4	140
2010	0	0	55	2218	10	97	4	181
2011	11	491	16	586	15	94	4	135
Total	11	491	126	8042	25	191	12	456

NB: OB= Outbreak

A total of 491 laboratory positive measles case were identified during outbreak searching. The beginning spurt of the outbreak was in the month of January, gradually increased and peaked at April-May and declined thereafter. Second episode also found in October and November. There was no single incidence of measles case in the month of September and December during the study period (Figure 3.30).

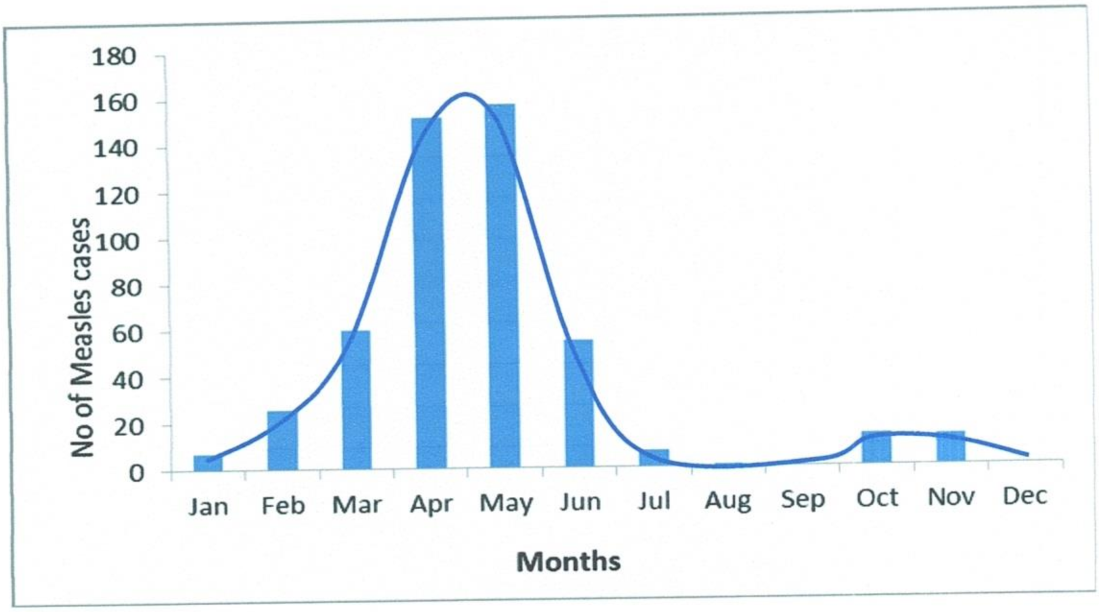


Figure 3.30 Presents the Epidemic Curve of Measles Outbreak in the Study Area during the study period (2009-2011)

The measles outbreak occurred in highly vaccinated population. Out of 491 total measles patients 309 (59.26%) cases were in between 9 months and 15 years old (Table-3.7).

Table 10 Vaccination status of Lab Confirmed Measles cases in the Study Area

Age group	Case	Vaccinated	Vaccination coverage
<9 months	12	0	0
9-11 months	17	10	59%
1-4 years	112	112	100%
5-9 years	111	100	90%
10-14 years	69	69	100%
9 months-<15 years	**309**	**291**	**94%**
15-19 years	56	45	80%
≥ 20 years	114	11	8%
Total	491	347	70.72%

Age distribution (Figure3.31), (Appendix-10) and sex distribution (Figure 3.32),(Appendix-11) revealed that measles disease affected irrespective of sex and ages. The graph showed that 75.9% of the measles cases under 15 years age group. 3.6%, 2.3%, 20.4%, 29.5%, 20.1% of the measles cases were <9 months, 9-11 months, 1-4 years, 5-9 years, 10-14 years age group respectively. Besides this there was 23% patient more than 20 years age.

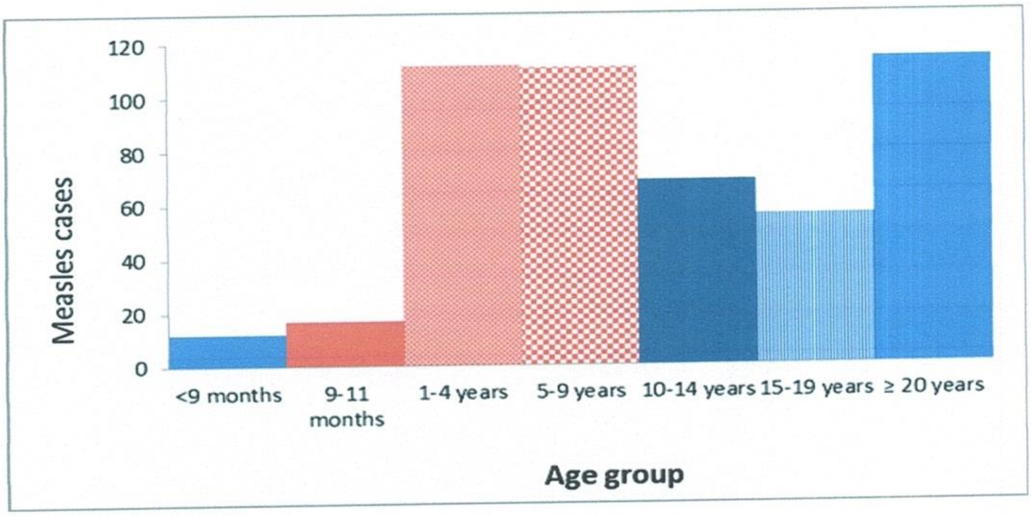


Figure 3.31 Age distribution of Measles cases in study area

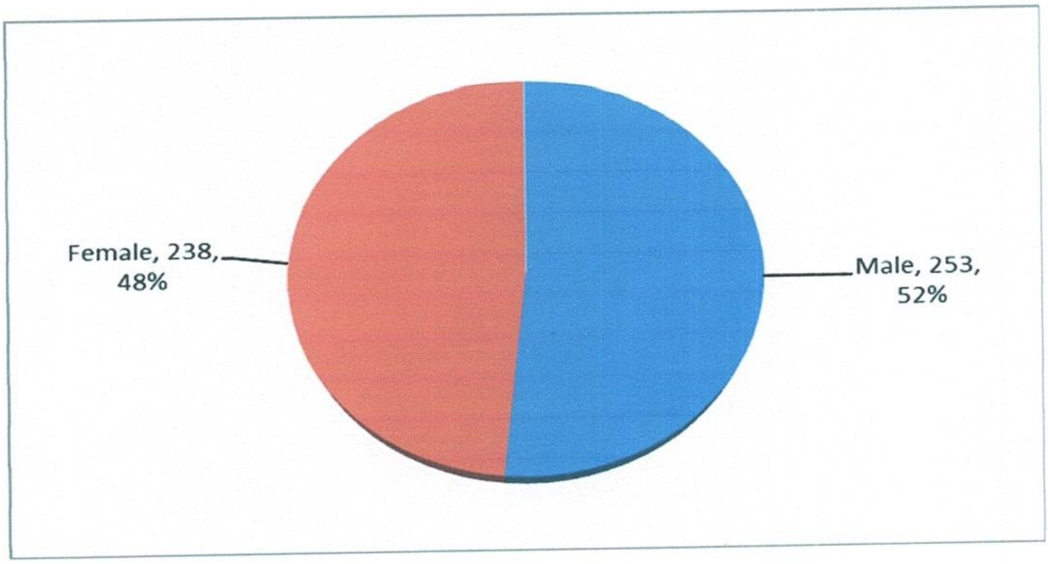


Figure 3.32 Sex Distribution of Measles Cases in the Study Area

Post measles complication: A period of one month after the attack of measles was taken into account for recording post measles complications. Parents reported one or more post measles complications in 54 cases out of 491cases. Diarrhoea was the commonest (74%) of all, followed by pneumonia (25%). There was no death due to measles like outbreak in the study area during the study period (2009-2011).

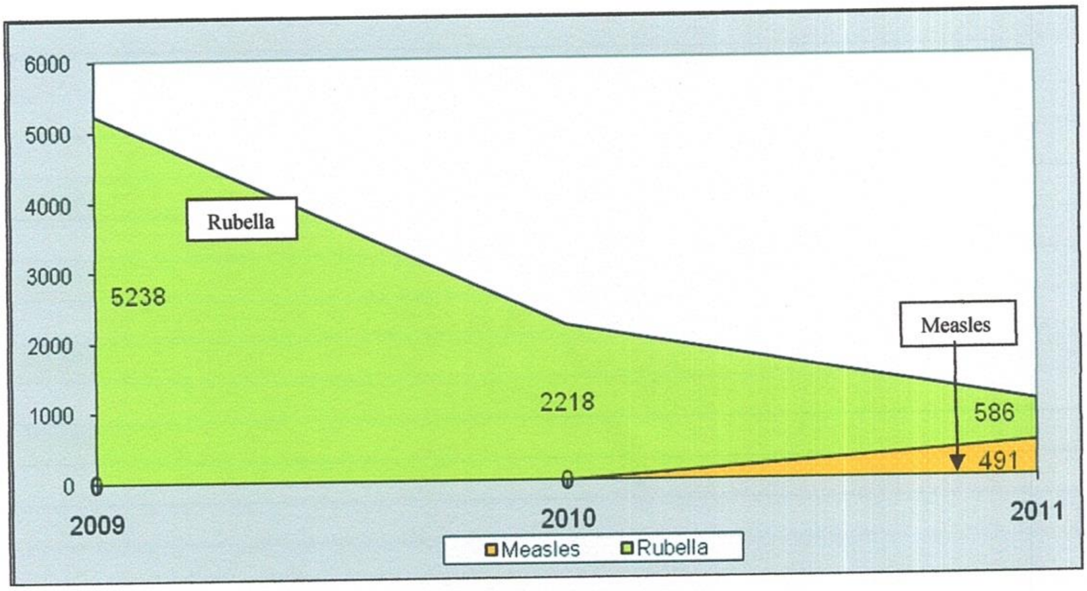


Figure 3.33 Comparison of Measles like Outbreak Cases by Lab result in the study area

Figure 3.33 showed that there was an enormous lab confirmed rubella outbreak and rubella case in the year 2009 consisting 5238 cases, in the year 2010 consisting 2218 cases and in the year 2011 consisting 586 cases. On the contrary there was no lab confirm outbreak of measles during 2009-2010 but 491 cases lab confirmed measles cases were diagnosed in 2011.

emerging infectious diseases which are also sensitive to weather and climatic variability (Epstain *et. al.,* 2006 and Hales, 2002).

Rising temperature and changing rainfall patterns are expected to have a substantial effect on the burden of infectious diseases transmitted by insect vectors and through contaminated water. Insect vectors are generally more active at higher temperatures, in addition to this there is an increased likelihood of them establishing themselves in new areas. The greatest effects of climate change on transmission are likely to be observed at the extreme ranges of temperatures at which transmission occur (Ranges between 14-18^{0}C and 35-40^{0}C) (Bradly, 1993).

Bangladesh is vulnerable to outbreaks of waterborne, airborne and vector borne infectious and other types of diseases (World Bank, 2000). Diseases such as diarrhoea, dysentery and measles like disease, etc. are also on the rise especially during the summer months. The medical communities of Bangladesh were fairly unfamiliar about the presence of dengue in Bangladesh before 2000. Since its outbreak started in summer of 2000, every year some cases are being reported. Nipah and Rubella are also emerging in previously unaffected areas with possibly changing epidemiology and severity of the disease. Rubella tends to cluster geographically and overlap with measles because they share some common features (WHO, SEAR report, 2009).

The present study has revealed changes in the trend of climate factors particularly yearly and seasonal mean, maximum and minimum temperature and rainfall over the last three decades in the study area. The long-term changes of temperature of study area over the period (1964-2011) found to have in general increasing trends in annual mean and annual mean minimum temperature but the annual mean maximum temperature slightly declining in recent past decade. Similar results were also observed by Ara *et. al.,* 2005 and Ferdous *et. al.,* 2011. The long-term seasonal mean temperatures were also found to have increasing trend. The highest average maximum temperature 30.55^{0}C observed in the month of April in pre monsoon season and lowest average 15.45^{0}C in the month of January in winter season. This observation was also supported by Climate Change Cell (CCC) and Tawhidul Islam *et. al.,* 2009.

The long-term changes in annual and seasonal rainfall in study area showed slightly decreasing trend with markedly reduced winter and post monsoon season rainfall in recent past decade supported by CCC, Bangladesh 2009 report and Ferdous *et. al.,* 2011. It declined, on average by 3.7mm over Bangladesh and 3.0698 mm/year in Rajshahi region. The present study also confirmed the above findings that the rainfall in Rajshahi region is on declining state.

The results of the study indicate that the climate factors including temperature and rainfall (seasonal and annual) are factors for causing infectious disease outbreak like diarrhoea, kala-azar, measles *etc.* in the study area. This finding is similar to the study done by CCC, Bangladesh 2009.

Regarding prevention and control of infectious diseases among children in Bangladesh, EPI program has successfully introduced vaccination against 8 vaccine preventable infectious diseases in the aim to reduce childhood morbidity and mortality. Bangladesh national EPI coverage evaluation survey 2009 stated BCG coverage 99%, which reflects the universal accessibility of the vaccination service while measles coverage was 79.4%. However, it is documented that vaccine efficacy for measles in 85 to 90% (WHO Global Immunization Vision and Strategy: 2006-2015, Bangladesh coverage Evaluation Survey 2009 and Thakur, 2002).

The result of the study showed that the children in the study area were highly vaccinated with 100 percent accessibility to vaccination schedule and the measles coverage was 86.20 percent. Among the vaccine preventable diseases only measles cases and outbreak found in the study area, these indicates vaccine preventable infectious diseases related morbidity and mortality reduced in the study area. These findings are consistent with Bangladesh Bureau of Statistics report 2009 and Bangladesh Demographic and Health Survey report 2011. Incidence of 78 measles like cases was found in 2009, 54 cases in 2010 and 104 cases in 2011 in the study area. Tracking the index case a total of 174 measles like outbreak were identified and investigated during study period. Measles vaccination status of identified measles cases of 9 months to 15 years was 94.17%, which indicates that vaccination failure occurred and susceptible accumulation caused measles outbreak in the study area. Vaccination failure may be due to inactive vaccine or inadequate host response. Besides this there was 23% patients of more than 20 years age. which was uncommon in measles epidemiology. It showed that there was a shift in age group affected towards higher side. Similar observations were also reported by Thakur, 2002, Sydenham, 1979 and London, 1973.

The measles like outbreak investigation data revealed that Rubella is an under diagnosed emerging infectious disease prevailing in the study area. In addition to laboratory confirmed measles outbreak a large number of measles like outbreak identified as laboratory confirm rubella outbreak which is newer in the study area. Rubella is a mild illness that presents with fever and rash which sometimes resembles that of measles. Rubella is relatively temperature labile but is more heat stable than measles virus. The public health importance of rubella is that infection in the early months of pregnancy usually affects foetal development and produce congenital rubella syndrome. So the above data indicates that there was large number of rubella cases in the study area and needs attention for assessing rubella and congenital rubella syndrome burden in the study area as well as in the country.

The correlation coefficients between climate factors and human health disorders varied. A positive correlation implies that the incidence of diseases increases as the variation of climatic variables increased. A negative correlation means decrease in the incidences of diseases when climatic variables level increased. Incidence of diarrhoea was found to have positive correlation with total annual and seasonal rainfall with highest in monsoon (+0.132) and winter (+0.193) rainfalls. The annual average maximum and minimum temperature was to be found positively correlated with the incidence of diarrhoea implies that diarrhoea as endemic in the study area. This finding is consistent with the study done by CCC, Bangladesh 2009 and ICDDRB published report 2009.

The incidences of diarrhoea have declined over time in Bangladesh. According to BDHS data 2007, the incidence rate is highest in Chitagong, Dhaka and Sylhet divisions (around 11 percent), while Rajshahi division reports the lowest incidence (7.6 percent). Figure-3.11 and appendix- 7 showed that the annual incidence of diarrhea in the study area over the study period have similar with the national findings.

Kala-azar is one of the major neglected disease in the world which been heavily impacted by the global climate change. The climate of Bangladesh is also changing which making people more prone to infectious diseases. The study area Rajshahi and Naogaon districts are kala-azar endemic district in Bangladesh

(Bangladesh Health Bulletin, 1998). Kala-azar was also found to be positively correlated with rainfall and annual average maximum temperature (+0.60). However, the correlation was found negative with annual average minimum temperature. A positive correlation implies that the incidence of kala-azar increases as the average maximum temperature increases and negative correlation (-0.635) means decrease in the incidence of kala-azar when average minimum temperature increased. The findings are similar to the study report by CCC, Bangladesh 2009 and Hamida Khannum *et. al.,*2010. It was found that most of the kala-azar patients were reported from high and medium high land barind areas. In contrast, kala-azar was found almost absent in plane and low land areas in the study districts. Almost all the kala-azar patients were from low socio-economic condition and living in kacha house. Study also revealed that the incidence of kala azar in the study area gradually decreases; this may be due to improve housing, decrease vector population as a result of residual spraying and improve kala azar case management. This trend coincides with the trends of kala-azar incidences in Bangladesh over all. Supported by Ramesh, 2010 and Hamida, 2010.

The incidence of measles like disease was found to reflect positive correlation with maximum temperature (+0.967) and negatively correlated with average minimum temperature (-0.003) and total annual rainfalls (-0.475). That is outbreak of measles like cases was found during the prevailing highest temperature in the month of March-May and declined after heavy rainfall and during winter months. Whereas the measles epidemics exhibit annual seasonality in which epidemics start in the autumn and peak in the spring (Fine & Clarkson, 1982, London and Yoke, 1973) in western country. This variation of seasons for measles outbreak might be due to the locale climatic variation which confirms the positive influence of climatic changes on infectious diseases.

In addition, climate factors are claimed to be associated with incidence of emerging Nipah virus infection in the study area. The outbreak of Nipah virus infection was found during the month of January through May in the study area. Nipah virus infection after the large outbreak in Malaysia, only three outbreaks have been reported from other than Bangladesh, one in Singapore and two in India. Since 2001 Nipah virus infection detected in northwest and central 20 district of Bangladesh (Chua *et. al.,* 2000-2003 and Homaira *et. al.,* 2007). Therefore, it is important to know whether specific environmental or host factors are responsible for recurrent transmission of Nipah virus to humans in specific areas of Bangladesh.

The survey respondents of the study also identified that the climatic factors, temperature and rainfall influence the outbreak of diarrhoea, kala-azar, measles like disease and newer Nipah virus infection among children.

Conclusions and Recommendations

Based on the findings of this study, the following conclusions are drawn:

1. The long-term changes in temperature of study area over the period (1964-2011) found to have in general increasing trends in annual mean and annual mean minimum temperature but the annual mean maximum temperature slightly declining in recent past decade.

2. The long-term seasonal mean temperatures were also found to have increasing trend. The highest average maximum temperature 30.55^0C observed in the month of April in pre monsoon season and lowest average 15.45^0C in the month of January in winter season.

3. The long-term changes in annual and seasonal rainfall in study area showed slightly decreasing trend with markedly reduced rainfall in winter and post monsoon season during recent past decade.

4. The results of the study indicate that the climatic factors including temperature and rainfall (seasonal and annual) are factors for infectious disease outbreak like diarrhoea, kala-azar, measles *etc.* among children in the study area.

5. The study disclosed that though measles vaccination coverage in the study area was 94.17% in 9 months to under 15 years age group nevertheless 309 incidences of measles cases were confirmed in the laboratory test. It might be either the vaccine was not up to the mark of efficacy or in some cases physiological or some other factors of the individuals were not synergistic to the vaccine.

6. Rubella outbreak is a new phenomenon was identified in the laboratory test, 126 outbreaks during the last three years certainly draw the attention to take care of it. It has been found that drought and high temperature favors the multiplication and transmission of the virus. The changing trends of rainfall and temperature in the study area may favor the rubella outbreak in coming days if appropriate measures could not be taken.

7. The outbreak of Nipah virus infection was found during the month of January through May in the study area and climatic factors are claimed to be associated with incidence of emerging Nipah virus infection. However, this aspect needs further study.

In spite of various limitations and constraints on the data related to climate variables and infectious disease report in the context of specific location of Bangladesh, an extensive and in-depth study should be undertaken for better understanding of the impacts of climate change on the outbreak of infectious diseases especially among children. The findings from such a study would be valuable for policy and decision making process relating human health and sustainable development.

On the basis of the findings of the study future initiatives are required in the following areas:

Increase in active infectious disease surveillance

- Disease surveillance data are needed to provide a baseline for further broad-based epidemiological studies. As these data are difficult to gather, particularly in sub national level, a centralized computer database should be created separately for climate sensitive infectious diseases as well as emerging and re-emerging infectious diseases with full demographic and epidemiological information.
- Community awareness program on climate change and its impact on health to build resilience should be held frequently.

Strengthen of routine Immunization programme

- Routine checking of child vaccination registration book shall have to ensure to find out the left out and drop out cases and to be vaccinated within scheduled time.
- Introduction of new vaccine to protect the children from vaccine preventable infectious diseases as like as rubella and others is obligatory.

Improvements in public health infrastructure

- These include training of health professionals on climate change and its impact on infectious diseases as well as human health, training on emergency response, and prevention and control programmes and increase awareness programmes among general people to deal with future adversity.

- The epilogue is that for ensuring public health constant keen observation, analyzing the changing climatic conditions, building up public awareness about the infectious diseases, early identification and routine checkup of the patients, appropriate vaccination after proper investigation, and well equipped and trained personnel are the indispensible prerequisites.
- Finally it may be recommended that further intensive research works throughout Bangladesh shall have to be carried out for developing effective control measures and management of the infectious diseases among children.

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Appendices

Appendix 1. Monthly and Annual Average Temperature of Rajshahi from 1964 to 2011

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1964	16.0	18.8	25.7	27.9	28.2	29.1	27.3	28.4	28.2	26.8	22.2	18.5	24.760
1965	17.3	19.1	22.8	28.0	29.2	28.7	28.0	27.9	28.0	26.7	22.5	17.7	24.662
1966	16.1	19.7	23.6	29.8	30.2	28.7	28.1	27.9	27.5	25.0	21.7	17.0	24.608
1967	16.2	19.5	23.8	28.2	30.8	29.4	27.8	27.5	27.4	25.5	20.1	17.2	24.450
1968	16.3	18.3	24.6	30.7	33.1	28.0	28.2	28.3	28.7	25.8	21.8	16.7	25.037
1969	16.8	18.9	24.7	29.7	29.1	28.8	28.1	27.8	27.9	25.8	21.7	17.0	24.692
1970	17.2	18.5	25.8	29.8	30.0	29.2	28.3	28.2	28.7	27.1	21.4	17.4	25.137
1971	16.8	18.5	25.4	29.3	29.3	28.1	27.8	27.9	28.1	26.5	22.1	17.8	24.800
1972	17.9	19.5	25.1	29.5	28.7	28.1	28.2	28.2	28.1	27.1	21.3	17.3	24.915
1973	18.6	20.4	25.4	29.6	28.0	28.6	28.5	28.7	28.0	27.2	22.1	18.2	25.280

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1974	17.2	19.7	24.9	29.1	28.5	29.5	27.3	27.9	27.8	26.9	21.7	17.2	24.808
1975	17.2	19.5	25.1	30.1	29.4	29.9	28.0	28.3	28.2	27.0	22.1	17.5	25.189
1976	17.0	19.5	25.9	29.3	27.9	28.4	27.6	27.5	27.9	27.3	22.1	17.2	24.800
1977	17.2	20.2	27.6	27.3	27.5	27.2	28.1	28.5	28.4	26.6	23.2	18.7	25.036
1978	17.4	20.3	23.9	28.1	28.0	27.9	28.3	28.3	27.9	27.4	23.3	18.5	24.939
1979	17.5	19.0	24.3	29.4	28.4	29.2	28.4	28.4	28.5	26.8	23.6	18.7	25.184
1980	17.1	19.8	24.8	31.7	28.2	28.6	28.5	28.8	28.8	26.3	23.0	19.2	25.402
1981	17.4	20.3	24.1	26.1	27.4	29.1	28.2	28.8	28.4	27.2	22.5	17.5	24.744
1982	17.8	19.4	23.4	27.9	30.5	28.8	29.4	28.1	29.2	26.5	21.6	17.6	25.027
1983	16.9	19.5	25.8	28.2	28.7	30.6	29.9	28.9	29.1	27.2	22.8	17.5	25.425
1984	16.4	18.8	25.5	30.2	29.0	28.2	28.0	28.4	28.0	27.2	21.9	17.9	24.955
1985	17.7	19.3	26.7	30.1	28.0	28.9	27.6	28.7	28.1	26.3	21.9	18.6	25.166
1986	17.5	20.0	25.7	27.8	28.2	29.5	28.4	29.2	27.4	25.5	22.8	18.9	25.058

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1987	17.4	20.9	25.5	28.5	30.2	29.8	28.0	28.3	28.7	27.1	22.8	18.9	25.523
1988	17.4	20.5	24.7	28.8	29.8	28.9	28.9	28.5	28.9	27.3	22.4	18.6	25.392
1989	16.6	20.1	24.9	30.5	30.3	29.4	28.7	29.2	28.5	27.3	22.3	17.5	25.442
1990	17.8	20.9	24.6	29.3	29.6	29.5	28.7	29.3	28.7	26.2	23.4	17.9	25.493
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1991	16.4	20.9	25.6	29.8	29.3	29.1	28.9	29.2	28.6	26.5	21.6	17.5	25.288
1992	16.7	18.8	26.1	30.8	29.4	30.2	28.5	29.1	28.8	26.7	21.9	17.4	25.367
1993	16.8	21.4	24.8	28.7	29.3	29.8	29.3	29.1	28.4	27.5	23.4	19.4	25.658
1994	17.9	19.3	25.4	28.7	30.2	28.9	28.9	29.1	28.3	26.8	22.7	17.9	25.342
1995	15.7	19.3	24.5	30.2	31.3	29.4	28.4	28.5	28.2	27.2	22.5	18.1	25.288
1996	17.4	20.3	26.7	29.5	30.7	28.8	29.2	28.9	29.3	26.7	22.3	17.9	25.642
1997	16.0	19.8	25.2	29.5	29.8	29.3	28.4	28.8	28.8	26.9	22.9	17.4	25.220
1998	15.1	19.9	22.8	27.6	29.5	30.9	28.9	29.0	28.6	27.8	24.3	19.1	25.302

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1999	17.0	21.3	26.0	30.9	29.1	29.4	28.5	28.5	27.8	27.1	22.9	19.3	25.650
2000	16.9	20.5	25.3	30.5	28.6	29.5	29.6	29.8	28.2	27.6	23.7	18.2	25.702
2001	15.9	20.0	24.8	29.3	27.8	28.6	28.9	29.5	28.7	27.1	23.5	17.7	25.147
2002	16.7	20.3	25.3	29.1	29.6	29.0	28.8	29.3	28.2	26.4	22.6	17.5	25.227
2003	17.1	20.5	25.3	29.5	29.8	29.4	28.9	29.4	28.4	26.5	22.8	18.8	25.533
2004	15.7	20.0	26.6	28.4	30.6	28.9	28.6	29.1	27.8	25.9	22.0	19.3	25.239
2005	16.9	21.6	25.7	29.2	29.3	30.4	28.7	29.2	29.0	26.0	21.5	18.6	25.493
2006	16.7	23.0	25.4	28.7	29.1	29.5	29.2	28.9	28.3	27.2	22.3	18.4	25.538
2007	17.5	20.5	26.2	30.2	30.7	29.6	29.1	29.8	29.2	27.3	23.0	18.2	25.938
2008	17.7	20.3	26.0	30.4	30.3	30.7	28.2	30.4	28.9	26.8	22.7	18.4	25.900
2009	17.5	20.3	25.0	30.0	28.9	31.0	29.3	28.9	28.9	26.3	22.8	17.3	25.527
2010	15.1	20.3	27.2	31.3	30.1	29.9	29.7	29.6	28.6	27.0	23.2	17.4	25.782
2011	15.45	17.9	26	30.55	29.25	31	29.95	29.65	29.4	26.7	23.8	20.55	25.85

Appendix 2. Monthly and Annual Maximum Temp of Rajshahi from 1964 to 2011

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1964	30.7	34.4	38.4	42.1	39.6	41.4	32.9	42.8	33.9	33.3	31.4	29.4	35.86
1965	27.9	31.6	36.6	41.7	41.7	40.6	33.9	34.3	34.9	33.7	33.4	29.4	34.98
1966	26.3	33.9	43.5	42.7	42.9	43.1	35.7	34.7	35.8	32.8	31.3	28.8	35.96
1967	31.2	33.8	34.7	39.4	43.3	40.4	34.4	35.8	33.9	33.9	30.4	27.8	34.92
1968	27.6	30.5	38.7	40.8	43.2	36.5	33.4	34.4	36.1	33.3	31.7	27.4	34.47
1969	27.6	30.5	38.7	40.8	43.2	36.5	33.4	34.4	36.1	33.3	31.7	27.4	34.47
1970	27.6	30.5	38.7	40.8	43.2	36.5	33.4	34.4	36.1	33.3	31.7	27.4	34.47
1971	26.6	30.9	38.7	40.8	43.2	34.8	34.7	35.6	35.9	31.6	29.4	27.4	34.13
1972	27.9	32.8	37.5	40.8	45.1	41.4	37.3	34.2	36.9	35.8	33	30.4	36.09
1973	33.4	34.2	41.2	42.2	37.3	36.7	34.7	33.6	33.6	32.8	31.5	26.9	34.84
1974	27.8	34.5	37.5	41.1	39.4	37.5	34	34.3	35	36	32.8	27.5	34.78

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1975	27.2	33	38.6	41	41.1	38.5	34.6	35	34	33.3	30.6	27	34.49
1976	28	33.3	37.2	40.6	42.2	36.1	35.6	33.6	33.9	34.4	33.2	29.4	34.79
1977	29	35	38.5	38.7	39	36.5	34.5	36.7	35.4	34.7	32.5	29.5	35.00
1978	28.5	31.8	35.5	37.5	37.1	35	33	33	33.5	33.1	31.2	27.5	33.06
1979	27.4	31.5	39.6	40.6	42	43.5	35.8	37.4	35.7	34.1	31	27	35.47
1980	28.6	32.2	38.2	44.4	40.8	38	34	38.5	34	33.5	30.5	28.5	35.10
1981	26.8	34.3	35.2	36.3	36.2	37.7	33.1	33.7	33.5	34	30.5	28.5	33.32
1982	26.8	34.3	35.2	36.3	38.4	37.5	38.3	33.8	35.4	35.1	32.2	27	34.19
1983	28.5	32.3	38.6	39.8	38.2	40.7	36.2	36.1	33.7	33.9	33.4	27.8	34.93
1984	26.6	29.6	38.7	42.5	40.2	38.1	33.6	35.1	33.8	34.1	30.6	28.6	34.29
1985	28.2	31.6	38.9	43.8	36	37.3	33.6	35	34	34	31.4	28	34.32
1986	29.4	32	41.5	41	40	40.8	34	35.5	35.2	32.1	31.5	29	35.17
1987	28	33.5	38.6	41	42.5	40.1	34.2	38	34.5	34.6	32.4	28.5	35.49

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1988	27.8	31.2	36.8	42	40.4	38.3	34	34.2	35.8	33.8	33.8	28	34.68
1989	26.7	33.7	37.9	42.7	43.7	36	36	35.4	35.2	34.5	32.4	28.3	35.21
1990	29.7	30.5	36.4	39.4	36.2	36.2	33.7	36.4	35.9	33.2	32.7	29.2	34.13
Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1991	29.3	34	38.7	40.2	40.2	35.2	35.3	36.1	35.3	35	32	29	35.03
1992	27.5	28.5	39.5	42.7	40.6	39.6	36.5	36	35.3	35	32.8	27.9	35.16
1993	31.6	34	37.3	39.6	39.2	37.6	34.6	34.4	34.9	34.5	31	29	34.81
1994	28.2	31.8	38	39.6	42.5	38.4	31.8	35	34.6	34.4	31.5	28.8	34.55
1995	26.5	29.6	39.8	42.2	43.3	38.6	34.2	34.8	34.5	34.6	33	28.4	34.96
1996	26.4	31.2	38.2	42	41.4	36.5	35.2	35.2	35.7	34.7	32.6	28	34.76
1997	26	30.8	36	37.4	40.2	38.5	34.8	35.8	34.2	33.7	32.6	27.5	33.96
1998	25.6	31.7	35.6	38.5	41.8	42.8	35.5	35	36	35.7	31.7	29.2	34.93
1999	28.5	34.3	38.7	41.8	39.8	39.7	34.9	35	34.2	33.1	32.5	29.1	35.13

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
2000	28.1	28.8	35.8	39.5	38.4	36.3	35.1	35.3	34.6	34.8	32	27.3	33.83
2001	28	31.6	37.9	40	37	35.2	34.5	35	35.5	34	33.2	27.5	34.12
2002	28	32.7	37.3	37.9	39.2	35.8	37.2	35.3	35.3	35	31.5	29.4	34.55
2003	26.1	33	35.8	40.3	41.4	38.6	34.8	35.5	34.6	34.4	31.6	29	34.59
2004	26	35	39.7	40.8	42.2	36.6	35.8	35	34.6	35	30.5	29	35.02
2005	26.4	33.2	36	38.6	39.8	42.8	34.3	36	36.2	33.6	30.8	27.8	34.63
2006	27.8	36.8	39.6	39	39	37.5	36.4	35.8	35.5	36	31.5	28.2	35.26
2007	28.3	30.5	37.4	39.4	40.2	39.8	36.7	36.8	35.6	35.5	32.5	28	35.06
2008	28.3	30.4	38.2	40	38	36	34.5	35.4	35.3	34	32	29	34.26
2009	24.5	29.5	33.4	37.5	35.1	36.4	33.5	32.6	33.5	33.5	31.9	31.9	32.78
2010	22.3	28.7	35.8	38.3	35.9	35	34	34	33.2	31.9	29.8	25.1	32.00
2011	19.7	22.5	33.6	37.5	34.3	36.2	33.9	32.9	33.7	29.8	31.3	28.6	31.17

Appendix 3. Monthly and Annual Minimum Temperature of Rajshahi from 1964 to 2011

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1964	5.8	8.6	12.4	18.3	20.6	22.4	23.9	24.7	24.2	21.4	13	8.7	17
1965	7.7	10.3	11.7	16.5	21.1	22.5	24.3	24	23.6	21.3	14.9	9.3	17.27
1966	6.5	9.4	10.2	19.2	19.4	23.3	23.8	24	22.4	19.3	14.1	7.3	16.58
1967	8.2	8.8	13.4	15.3	20.1	21.6	24.7	25.1	23.2	18.2	12.9	9.7	16.77
1968	7.7	6.9	14.6	14.8	16.9	21.2	24.4	23.6	14.4	18.2	14.2	7.1	15.33
1969	7.7	6.9	14.6	14.8	16.9	21.2	24.4	23.6	14.4	21.1	12.8	10.6	15.75
1970	7.7	6.9	14.6	14.8	16.9	21.2	24.4	23.6	14.4	21.1	12.8	10.6	15.75
1971	8.7	8.5	13.4	15.3	21.4	22.3	24.6	10.4	24.2	16.4	13.9	10.6	13.42
1972	8.3	8.4	11.8	19.2	21.2	22.8	23.6	23.6	18.3	19.7	15.7	9.4	16.83
1973	8.5	9.8	12.8	20.1	21.7	22.4	24.4	23.9	23.1	19.9	15.6	9.4	17.63
1974	7.8	7.2	15.8	19.4	19.4	21.4	23.6	23.9	23.7	19.4	15	10.6	17.27
1975	8.9	10	15.5	18.3	19.4	21.1	23.3	24.4	23.9	22.8	11.8	9.5	17.41

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1976	9.3	12.2	12.8	20	18.9	21.8	25	22.8	23.3	20	13.9	10	17.50
1977	8.3	8.9	15.6	19.1	16.1	19.7	24.4	24.3	23.2	20.6	16.1	12.2	17.38
1978	8.3	9.8	10.3	18.3	19.7	21.9	24.4	24.4	23.3	20.6	11.9	10.4	16.94
1979	9.2	10.2	11.3	18.6	16.4	22.2	24.3	23.4	16.2	21.4	17	8.3	16.54
1980	8.7	6.9	11.4	20.4	19.4	22.8	24.4	23.5	24.4	20.8	14.4	10	17.26
1981	9	10.6	12.2	16.3	19.8	19.3	23.1	24.8	22.8	17.9	12.1	8.3	16.35
1982	7.8	9	12.8	18.6	21.7	23	23.3	23.9	22.8	18.5	8.9	8.8	16.59
1983	6.3	5	11.4	16.4	20.8	22.3	24	23.5	24.4	18.8	14.4	7.2	16.21
1984	7.1	7.9	9.5	18.2	19.4	23.5	24	23.6	22	19.3	14.5	8	16.42
1985	8.8	8.5	13.2	19.5	19.3	22.4	23.6	24.8	23.5	17.8	11.5	8	16.74
1986	7.6	8.5	13	16.5	19.5	22.2	24	23.5	21.5	17.8	14.5	9.6	16.52
1987	7.2	9	14.4	18.5	18	22.4	23.3	23.5	21.2	17.2	11.8	9	16.29
1988	7.4	9.3	13.4	17.2	20.7	22.4	24	23.3	22.4	19	12.5	11.6	16.93

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1989	4.6	7.2	10.2	14.9	19.8	22.6	22.7	23.7	19.4	19	13.5	6.2	15.32
1990	6	9.5	11.9	13.8	19.3	21.6	24.2	23.5	22	14.5	9.5	6.6	15.20
Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
1991	5.2	10.2	13	17.2	19	22.2	24	23.2	23	18.8	10.5	7.5	16.15
1992	7.2	8.5	12.6	17.5	18	22	23.9	23.2	21.7	15.8	13.4	7.8	15.97
1993	5.2	7.2	11.4	17.2	19.8	22.2	24.3	25.2	23.5	18.8	13.8	10.5	16.59
1994	8.6	9	11.6	17.5	20.4	22.4	24.5	24.5	21.2	19	13.3	9	16.75
1995	4.7	8.4	11.5	17.1	21.8	22.8	24.2	24.3	23.2	19.4	10.5	9.8	16.48
1996	6.3	8	13.4	15.2	20	21.2	24.8	23.6	23.3	19.7	11.8	8.6	16.33
1997	6.4	7.3	15	17	21	23	24	24	23	18.6	14.8	8	16.84
1998	6.4	9.2	11.4	17	20.3	25.7	25	25.4	23.2	19.6	14.8	10.4	17.37
1999	7.4	7.5	12.7	20.3	20.5	24	20.7	24.2	23.8	21.8	14	11.5	17.37
2000	5.8	8.8	13	18.9	20.5	24.2	25.3	24.5	23.2	19	16.2	10.2	17.47

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVR
2001	6.4	8.5	11.8	19.5	20.2	23.2	25	24.4	24.5	21.4	14.4	10.3	17.47
2002	8.4	8	12.6	17	19.5	23.8	23.4	24.1	24.2	16.2	14.3	9.2	16.73
2003	3.4	11.4	10.6	20.4	20.2	22.7	24.6	25.1	23.6	22.2	11.8	9.5	17.13
2004	8.2	8.6	12.5	19.5	21.4	23	23.5	24.5	21.5	19.5	14.2	7.7	17.01
2005	7.5	8.9	15.2	18.9	19.2	24	24	25.4	23.4	19.6	12.1	9.2	17.28
2006	6.5	12.8	13.7	18.5	19	22.5	25.2	24.5	24	20.5	10.4	9.4	17.25
2007	6.2	10.6	11.9	18.5	20.9	20.8	23.4	24.5	24.1	19.6	14.5	7.3	16.86
2008	6.8	6.7	14.4	17.8	20.3	22.6	24.8	25	24.5	17.9	12	10	16.90
2009	12.4	12.6	18.4	23.9	24.4	26.6	25.5	26.4	25.9	22.1	17.8	11.6	20.63
2010	9.3	13.1	19.8	25.6	25.4	26	26.6	26.6	25.4	23.4	18.4	11.8	20.95
2011	11.2	13.3	18.4	23.6	24.2	25.8	26	26.4	25.1	23.6	16.3	12.5	20.53

Appendix 4. Seasonal and Annual Mean Temperature of Rajshahi from 1964 to 2011

Year	Winter Mean temp	Summer mean temp.	Monsoon mean temp.	Annual mean minimum Temp.	Annual mean Temp.	Annual mean maximum Temp.
1964	17.80	27.28	28.23	17.00	24.77	35.86
1965	18.05	26.67	28.14	17.27	24.66	34.98
1966	17.60	27.87	28.05	16.58	25.22	35.96
1967	17.63	27.60	28.03	16.77	25.15	34.92
1968	17.09	29.45	28.31	15.33	25.08	34.47
1969	17.57	27.83	28.15	15.75	26.32	34.47
1970	17.70	28.53	28.60	15.75	26.38	34.47
1971	17.70	28.00	27.98	13.42	26.43	34.13
1972	18.23	27.77	28.14	16.83	26.58	36.09
1973	19.07	27.66	28.46	17.63	25.77	34.84
1974	18.03	27.50	28.13	17.27	25.81	34.78
1975	18.07	28.20	28.59	17.41	26.01	34.49

Year	Winter Mean temp	Summer mean temp.	Monsoon mean temp.	Annual mean minimum Temp.	Annual mean Temp.	Annual mean maximum Temp.
1976	17.90	27.70	27.85	17.50	25.94	34.79
1977	18.70	27.46	28.05	17.38	25.47	35.00
1978	18.74	26.67	28.08	16.94	24.94	33.06
1979	18.40	27.35	28.63	16.54	25.99	35.47
1980	18.72	28.25	28.64	17.26	25.40	35.10
1981	18.40	25.86	28.61	16.35	24.74	33.32
1982	18.27	27.26	28.89	16.59	25.01	34.19
1983	17.97	27.57	29.63	16.21	24.89	34.93
1984	17.67	28.25	28.16	16.42	24.95	34.29
1985	18.55	28.27	28.33	16.74	25.18	34.32
1986	18.77	27.24	28.60	16.52	25.04	35.17
1987	19.07	28.10	28.72	16.29	25.51	35.49
1988	18.83	27.77	28.80	16.93	25.43	34.68

Year	Winter Mean temp	Summer mean temp.	Monsoon mean temp.	Annual mean minimum Temp.	Annual mean Temp.	Annual mean maximum Temp.
1989	18.07	28.57	28.95	15.32	25.01	35.21
1990	18.87	27.83	29.05	15.20	24.80	34.13
1991	18.28	28.24	28.95	16.15	24.99	35.03
1992	17.63	28.77	29.15	15.97	25.07	35.16
1993	19.20	27.60	29.15	16.59	24.98	34.81
1994	18.37	28.10	28.80	16.75	25.06	34.55
1995	17.72	28.67	28.65	16.48	25.27	34.96
1996	18.54	28.97	29.05	16.33	25.29	34.76
1997	17.73	28.15	28.81	16.84	24.64	33.96
1998	18.04	26.66	29.36	17.37	25.28	34.93
1999	19.21	28.66	28.54	17.37	25.64	35.13
2000	18.54	28.13	29.28	17.47	24.93	33.83
2001	17.85	27.31	28.92	17.47	25.13	34.12

Year	Winter Mean temp	Summer mean temp.	Monsoon mean temp.	Annual mean minimum Temp.	Annual mean Temp.	Annual mean maximum Temp.
2002	18.17	28.00	28.81	16.73	25.11	34.55
2003	18.80	28.20	29.03	17.13	25.10	34.59
2004	18.35	28.53	28.59	17.01	25.24	35.02
2005	19.02	28.04	29.30	17.28	25.50	34.63
2006	19.36	27.70	28.96	17.25	25.55	35.26
2007	18.73	29.03	29.43	16.86	25.03	35.06
2008	18.80	28.90	29.55	16.90	25.10	34.26
2009	18.38	27.97	29.52	20.63	25.53	32.78
2010	17.63	29.52	29.44	20.95	26.48	32.00
2011	17.97	28.60	30.00	20.53	25.85	31.17

Appendix 5. Monthly and Annual Rainfall of Rajshahi from 1964 to 2011

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1964	0	0	0	138	114	415	346	169	242	286	0	0	1710
1965	0	21	61	22	149	277	404	227	171	75	19	0	1426
1966	36	0	1	16	106	293	511	380	265	90	14	1	1713
1967	15	2	50	95	70	140	305	210	195	60	0	1	1143
1968	0	1	24	9	152	296	439	270	103	122	4	0	1420
1969	0	1	24	9	152	296	439	270	103	122	4	0	1420
1970	8	4	27	45	125	284	409	256	174	123	7	0	1462
1971	22	14	27	45	125	277	452	452	264	81	86	48	1893
1972	10	13	0	19	88	208	109	248	175	51	0	0	921
1973	11	17	32	46	186	491	271	137	586	145	5	19	1946
1974	0	0	92	10	91	172	513	452	263	143	0	0	1736
1975	9	5	12	61	109	71	381	179	197	125	63	0	1212

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1976	0	10	4	10	235	234	242	389	257	45	1	0	1427
1977	4	19	0	229	241	543	399	157	121	162	10	33	1918
1978	1	46	62	93	104	492	126	149	545	92	24	0	1734
1979	45	17	2	35	13	46	492	275	379	188	28	28	1548
1980	29	12	69	0	156	349	281	316	215	149	0	0	1576
1981	71	49	26	240	290	159	574	340	398	0	3	91	2241
1982	0	10	80	139	43	260	189	217	66	38	60	1	1103
1983	1	2	4	34	121	65	366	505	149	358	0	24	1629
1984	31	1	0	10	94	325	294	321	297	202	0	0	1575
1985	4	7	3	97	190	232	274	146	233	77	3	12	1278
1986	3	12	19	93	81	175	262	238	406	190	27	4	1510
1987	0	4	12	76	102	295	488	400	193	43	5	4	1622
1988	1	30	36	107	139	404	301	195	89	94	27	0	1423

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1989	4	8	5	2	224	190	357	117	332	78	0	8	1325
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1990	0	34	46	97	301	263	464	238	180	127	17	0	1767
1991	6	0	19	25	157	211	286	96	484	122	0	92	1498
1992	1	33	0	16	121	85	244	185	124	29	5	0	843
1993	0	5	55	70	65	477	247	177	316	157	54	0	1623
1994	18	36	5	31	115	237	171	206	171	130	22	0	1142
1995	17	31	9	8	91	291	287	270	370	13	44	1	1432
1996	0	21	4	73	95	284	106	270	298	118	0	0	1269
1997	8	35	19	56	53	242	763	468	348	4	44	22	2062
1998	16	5	52	33	129	92	404	268	310	198	33	0	1540
1999	0	0	0	9	144	348	349	354	502	155	1	0	1862
2000	4	47	27	136	198	222	115	192	644	85	0	0	1670

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
2001	0	0	9	13	209	324	338	209	95	184	1	0	1382
2002	10	1	20	96	196	222	316	238	281	48	17	0	1445
2003	3	18	64	45	84	280	230	128	262	292	0	6	1412
2004	10	0	0	61	92	507	339	275	349	153	0	0	1786
2005	14	1	104	27	108	92	492	161	131	275	0	0	1405
2006	0	0	7	36	189	188	130	247	302	36	10	0	1145
2007	0	27	59	13	260	313	364	236	309	76	1	0	1658
2008	26	0	0	30	144	247	373	245	129	121	0	0	1315
2009	1	7	28	0	132	154	155	292	45	0	0	0	814
2010	0	2	2	37	75	211	182	239	281	44	0	0	1073
2011	1	2	26	30	100	126	180	128	165	123	2	0	883

Appendix 6. Seasonal and Annual Rainfall of Rajshahi from 1964 to 2011

Year	Winter	Summer	Monsoon	Post monsoon	Annual
1964	0	252	1458	286	1710
1965	21	232	1154	94	1426
1966	37	123	1539	104	1713
1967	18	215	910	60	1143
1968	1	185	1230	126	1420
1969	1	185	1230	126	1420
1970	12	197	1246	130	1462
1971	84	197	1526	167	1893
1972	23	107	791	51	921
1973	47	264	1630	150	1946
1974	0	193	1543	143	1736
1975	14	182	953	188	1212

Year	Winter	Summer	Monsoon	Post monsoon	Annual
1976	10	249	1167	46	1427
1977	56	470	1382	172	1918
1978	47	259	1404	116	1734
1979	90	50	1380	216	1548
1980	41	225	1310	149	1576
1981	211	556	1471	3	2241
1982	11	262	770	60	1103
1983	27	159	1443	0	1629
1984	32	104	1439	0	1575
1985	23	290	962	3	1278
1986	19	193	1271	27	1510
1987	8	190	1419	5	1622
1988	31	282	1083	27	1423

Year	Winter	Summer	Monsoon	Post monsoon	Annual
1989	20	231	1074	0	1325
1990	34	444	1272	17	1767
1991	98	201	1199	0	1498
1992	34	137	667	5	843
1993	5	190	1374	54	1623
1994	54	151	915	22	1142
1995	49	108	1231	44	1432
1996	21	172	1076	0	1269
1997	65	128	1825	44	2062
1998	21	214	1272	33	1540
1999	0	153	1708	1	1862
2000	51	361	1258	0	1670
2001	0	231	1150	1	1382

Year	Winter	Summer	Monsoon	Post monsoon	Annual
2002	11	312	1105	17	1445
2003	27	193	1192	0	1412
2004	10	153	1623	0	1786
2005	15	239	1151	0	1405
2006	0	232	903	10	1145
2007	27	332	1298	1	1658
2008	26	174	1115	0	1315
2009	8	159	876	0	1043
2010	2	114	957	0	1073
2011	3	156	722	2	883

Appendix 7. Monthly Diarrhoea Report in the study area from 2000 to 2010

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total
2000	5550	5623	6373	5719	5525	4415	5893	5710	8152	15037	6999	5371	80367
2001	6383	4928	5290	6161	6523	5562	6110	4916	6512	7281	6954	6618	73238
2002	6920	5953	6196	5685	5416	5363	4583	6652	7450	8234	10503	12289	85244
2003	7833	6504	6502	5962	5789	4931	8097	8887	7579	7171	7367	8282	84904
2004	6298	5593	5266	5274	5318	6317	6923	9184	7564	9553	7667	14983	89940
2005	9549	7080	6111	7593	7371	7394	6376	7878	7152	7882	7199	8456	90041
2006	7908	5809	6572	5605	7634	7246	8644	7532	6886	7400	7168	5300	83704
2007	6784	6773	8280	8696	8693	9261	9167	11359	11289	10189	8923	9193	108607
2008	9155	7315	8626	9098	8366	8744	10919	8370	7428	8209	8403	9006	103639
2009	8123	8896	9928	12737	10677	12455	11165	10604	10378	11853	10486	9017	126319
2010	11166	12297	13002	13615	13193	11382	14210	12904	10604	11078	10897	9495	143843
2011	8265	8790	10124	10421	11404	9619	10320	11112	11364	12972	11842	10479	126712
Total	93934	85561	92270	96566	95909	92689	102407	105108	102358	116859	104408	108489	1196558

Appendix 8. Yearly and seasonal onset of Infectious disease in the study area

year	winter_ diarrhoea	summer_ diarrhea	monsoon_ diarrhoea	postmonsoon_ diarrhoea	total- diarrhoea	winter_ rainfall	summer_ rainfall	monsoon_ rainfall	postmonsoon_ rainfall	kalaazar	total_ rainfall	maximum temp	minimum temp
2000	16544	17617	24170	22036	44808	51	361	1258	85		1670	33.83	17.47
2001	17929	17974	23100	14235	34994	0	231	1150	185	154	1382	34.12	17.47
2002	25162	17297	24048	18737	38993	11	312	1105	65	198	1445	34.55	16.73
2003	22619	18253	29494	14538	41091	27	193	1192	292	165	1412	34.59	17.13
2004	26874	15858	29988	17220	42634	10	153	1623	153	103	1786	35.02	17.01
2005	25085	21075	28800	15081	57958	15	239	1151	275	99	1405	34.63	17.28
2006	19017	19811	30308	14568	63128	0	232	903	46	105	1145	35.26	17.25
2007	22750	25669	41076	19112	83251	27	332	1298	77	129	1658	35.06	16.86
2008	25476	26090	35461	16612	76765	26	174	1115	121	40	1315	34.26	16.90
2009	26036	33342	44602	22339	96764	8	159	876	45	87	814	32.78	20.63
2010	32958	39810	49100	21975	114779	2	114	957	44	14	1073	32.00	20.95
2011	27534	31949	42415	24814	96918	3	156	722	125	47	883	31.17	20.53

Appendix 9. Possible reasons for infectious disease incidence in the study area

Possible cause	Disease		
	Diarrhoea	Measles	Kala azar
Temperature variation	44%	74%	41%
Rainfall	29%	3%	33%
Water pollution	13%	2%	3%
Natural digester	8%	8%	3%
Don't know	4%	9%	6%
Others	2%	4%	14%

Appendix 10. Age group of Measles like cases in the study area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1. <9 MONTHS	329	3.6	3.6	3.6
	2. 9-11 MONTHS	214	2.3	2.3	5.9
	3. 1-4 YEARS	1873	20.4	20.4	26.3
	4. 5-9 YEARS	2709	29.5	29.5	55.8
	5. 10-14 YEARS	1842	20.1	20.1	75.9
	6. 15-19 YEARS	746	8.1	8.1	84.0
	7. 20-24 YEARS	544	5.9	5.9	89.9
	8. 25 AND ABOVE	923	10.1	10.1	100.0
	Total	9180	100.0	100.0	

Statistics of Age group of Measles like cases in the study area

N	Valid	9180
	Missing	0
Mean		128.40
Median		96.00
Std. Deviation		113.483
Minimum		0
Maximum		960

Appendix 11. SEX of Measles like cases in the study area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-MALE	4428	48.2	48.2	48.2
	2-FEMALE	4752	51.8	51.8	100.0
	Total	9180	100.0	100.0	

Appendix 12. Seasonal onset of Measles like cases with Laboratory result in the study area

			RESULT				Total
			Measles	Mixed Measles and Rubella	Non Measles Non Rubella	Rubella	
SEASON	Monsoon	Count	65	0	56	358	479
		% within SEASON	13.6%	.0%	11.7%	74.7%	100.0%
		% within RESULT	13.2%	.0%	12.3%	4.5%	5.2%
	Post-monsoon	Count	25	0	0	0	25
		% within SEASON	100.0%	.0%	.0%	.0%	100.0%
		% within RESULT	5.1%	.0%	.0%	.0%	.3%
	Pre-monsoon	Count	368	132	322	6920	7742
		% within SEASON	4.8%	1.7%	4.2%	89.4%	100.0%
		% within RESULT	74.9%	69.1%	70.6%	86.0%	84.3%
	Winter	Count	33	59	78	764	934
		% within SEASON	3.5%	6.3%	8.4%	81.8%	100.0%
		% within RESULT	6.7%	30.9%	17.1%	9.5%	10.2%
Total		Count	491	191	456	8042	9180
		% within SEASON	5.3%	2.1%	5.0%	87.6%	100.0%
		% within RESULT	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix 13. Correlations between total rainfall and Measles cases in the study area

		rainfall	total_measles
Rainfall	Pearson Correlation	1	.685
	Sig. (2-tailed)		-.475
	N	12	3
total_measles	Pearson Correlation	.685	1
	Sig. (2-tailed)	-.475	
	N	3	3

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

Appendix 14. Correlations between winter rainfall and winter measles cases reported in the study area

		winter_rainfall	**winter_measles**
winter_rainfall	Pearson Correlation	1	.288
	Sig. (2-tailed)		.899
	N	12	3
winter_measles	Pearson Correlation	.288	1
	Sig. (2-tailed)	.899	
	N	3	3

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

Appendix 15 Correlations between summer rainfall and summer measles cases reported in the study area

		summer_rainfall	**summer_measles**
summer_rainfall	Pearson Correlation	1	.851
	Sig. (2-tailed)		.233
	N	12	3
summer_measles	Pearson Correlation	.851	1
	Sig. (2-tailed)	.233	
	N	3	3

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

Appendix 16. Correlations between monsoon rainfall and monsoon measles cases reported in the study area

		monsoon_rainfall	monsoon_measles
monsoon_rainfall	Pearson Correlation	1	.917
	Sig. (2-tailed)		-.131
	N	12	3
monsoon_measles	Pearson Correlation	.917	1
	Sig. (2-tailed)	-.131	
	N	3	3

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

Appendix 17. Correlations between post monsoon rainfall and post monsoon measles cases reported in the study area

		postmonsoon_rainfall	postmonsoon_measles
postmonsoon_rainfall	Pearson Correlation	1	.007
	Sig. (2-tailed)		1.000**
	N	12	3
postmonsoon_measles	Pearson Correlation	.007	1
	Sig. (2-tailed)	1.000**	
	N	3	3

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

Appendix 18. Correlations between maximum temperature and measles cases reported in the study area

		maximum temp	total_measles
maximum temp	Pearson Correlation	1	.163
	Sig. (2-tailed)		.967
	N	12	3
total_measles	Pearson Correlation	.163	1
	Sig. (2-tailed)	.967	
	N	3	3

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

Appendix 19. Correlations between minimum temperature and measles cases reported in the study area

		minimum temp	total_measles
minimum temp	Pearson Correlation	1	.998
	Sig. (2-tailed)		-.003
	N	12	3
total_measles	Pearson Correlation	.998	1
	Sig. (2-tailed)	-.003	
	N	3	3

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

Appendix 20. Correlations between total rainfall and diarrhoea cases reported in the study area

		rainfall	Totaldiarrhoea
Rainfall	Pearson Correlation	1	-.675*
	Sig. (2-tailed)		.016
	Sum of Squares and Cross-products	1025896.667	-61426774.667
	Covariance	93263.333	-5584252.242
	N	12	12
Totaldiarrhoea	Pearson Correlation	-.675*	1
	Sig. (2-tailed)	.016	
	Sum of Squares and Cross-products	-61426774.667	8.074E9
	Covariance	-5584252.242	7.340E8
	N	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 21. Correlations between winter rainfall and winter diarrhoea cases reported in the study area

		winter_rainfall	winter_diarrhoea
winter_rainfall	Pearson Correlation	1	-.404
	Sig. (2-tailed)		.193
	Sum of Squares and Cross-products	2558.000	-310074.000
	Covariance	232.545	-28188.545
	N	12	12
winter_diarrhoea	Pearson Correlation	-.404	1
	Sig. (2-tailed)	.193	
	Sum of Squares and Cross-products	-310074.000	2.306E8
	Covariance	-28188.545	20963185.697
	N	12	12

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

Appendix 22 Correlations between summer rainfall and summer diarrhoea cases reported in the study area

		summer_rainfall	summer_diarrhoea
summer_rainfall	Pearson Correlation	1	-.547
	Sig. (2-tailed)		.065
	Sum of Squares and Cross-products	67880.667	-3647455.000
	Covariance	6170.970	-331586.818
	N	12	12
summer_diarrhoea	Pearson Correlation	-.547	1
	Sig. (2-tailed)	.065	
	Sum of Squares and Cross-products	-3647455.000	6.541E8
	Covariance	-331586.818	59463227.295
	N	12	12

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

Appendix 23. Correlations between monsoon rainfall and monsoon diarrhoea cases reported in the study area

		monsoon_rainfall	monsoon_diarrhoea
monsoon_rainfall	Pearson Correlation	1	-.460
	Sig. (2-tailed)		.132
	Sum of Squares and Cross-products	601955.000	-10422684.000
	Covariance	54723.182	-947516.727
	N	12	12
monsoon_diarrhoea	Pearson Correlation	-.460	1
	Sig. (2-tailed)	.132	
	Sum of Squares and Cross-products	-10422684.000	8.525E8
	Covariance	-947516.727	77501532.152
	N	12	12

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

Appendix 24. Correlations between post monsoon rainfall and post monsoon diarrhoea cases reported in the study area

		postmonsoon_rainfall	postmonsoon_diarrhea
postmonsoon_rainfall	Pearson Correlation	1	-.557
	Sig. (2-tailed)		.060
	Sum of Squares and Cross-products	81480.917	-1920900.917
	Covariance	7407.356	-174627.356
	N	12	12
postmonsoon_diarrhoea	Pearson Correlation	-.557	1
	Sig. (2-tailed)	.060	
	Sum of Squares and Cross-products	-1920900.917	1.458E8
	Covariance	-174627.356	13255470.447
	N	12	12

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

Appendix 25 Correlations between maximum temperature and diarrhoea cases reported in the study area

		maximum temp	Totaldiarrhoea
maximum temp	Pearson Correlation	1	-.685*
	Sig. (2-tailed)		.014
	Sum of Squares and Cross-products	18.370	-263874.104
	Covariance	1.670	-23988.555
	N	12	12
Totaldiarrhoea	Pearson Correlation	-.685*	1
	Sig. (2-tailed)	.014	
	Sum of Squares and Cross-products	-263874.104	8.074E9
	Covariance	-23988.555	7.340E8
	N	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix-I

Impact of climate change on the outbreak of infectious disease among children in Bangladesh: it's prevention and control Survey Form

Cluster No: **District:** **Upz/Mun/CC:**

Union/Ward: **Vill/Mohallah:**

	No of Familly member	**<9 month**	**9m-11m**	**1-4 Yr**	**5-9 Yr**	**10-14 Yr**	**15-19 Yr**	**20 &>**
	Total:							
	Sex (M/F)							
	Experience of Infectious disease* within 10 year							
	Climatic factors** responsible for the disease							
1	Death within 10 yrs with probable cause*							
	Vaccination status of <5 years children (Y/N)	DOB:		BCG	DPT 3		Measles	
	Education and Occupation of Mother							
	Education and Occupation of Father							
	Knowledge about climate change***							
	Monthly income							

NB: * probable causes of infectious disease- Diarrhoea, Kala azar, Measles, Malaria, NIPAH.
** Temperature variation, Rainfall variation, Water pollution, Natural disasters, Don't know, Others.
*** Changes of weather for long time, Chage of temperature or rainfall, Don't know, Others

Signature

Appendix-II

AFP & EPI Disease Weekly Line Listing Form for Hospitals and Upazila Health Complexes

Facility Name ______________________ City Corporation/ Municipality/ Upazilla ____________________

District __________________

Reporting Epidemiologic week no: ______ Date from (Sunday)__________ to (Saturday)__________
(dd/mm/yy) *(dd/mm/yy)*

<u>Summary number of cases</u>:

Measles: [ ] Diarrhoea [ ] Kala azar [ ] Other [ ] infectious [ ] disease

Sl. No	Disease	Patient name	Sex (M/F)	Patient's detailed address at time of infection including house #/ name, village/road/mahalla, ward, union, upazila/municipality and district whichever applicable	Date of birth (dd/mm/yy)	Date of symptom onset	Date of hospital visit (dd/mm/yy)	Fully Vaccinated against this disease	Date case died (dd/mm/yy) (if applicable)

Prepared by: ____________________ __________ ____________ __________ Submitted by: ______________

Name Designation Signature Date Name Designation Signature Date

Appendix-III

Impact of climate change on the outbreak of infectious disease among children in Bangladesh: it's prenvetion and control

আউটব্রেক অনুসন্ধানঃ হামের রোগী অনুসন্ধান

হামের আউটব্রেক আইডেন্টিফিকেশন নাম্বারঃ

গ্রামঃ ওয়ার্ডঃ ইউনিয়ন/জোনঃ

উপজেলা/পৌরসভাঃ সিটি কর্পোরেশনঃ জেলাঃ

অনুসন্ধানের তারিখঃ অনুসন্ধানকারীঃ

ক্রমিক নং	বয়স সীমা	হামের টিকা প্রাপ্ত ব্যক্তির সংখ্যা (এ)		হামের টিকা না পাওয়া ব্যক্তির সংখ্যা (বি)		হামের রোগীর সংখ্যা (সি)		বয়সভিত্তিক টিকার অর্জন (%)
		ট্যালি	সংখ্যা	ট্যালি	সংখ্যা	ট্যালি	সংখ্যা	
১	< ৯ মাস							
২	৯ মাস - < ১ বছর							
৩	১ - ৪ বছর							
৪	৫ - ৯ বছর							
৫	১০ - ১৪ বছর							
৬	১৫ - ১৯ বছর							
৭	>= ২০ বছর							
			0		0		0	

লক্ষণীয়ঃ ১. যাদের বর্তমানে হাম হয়েছে অথবা হামে আক্রান্ত ছিল (কলাম "সি" অনুযায়ী) তাদের বিস্তারিত তথ্য ফর্ম-২ তে লিপিবদ্ধ করন ।

Appendix-IV

Impact of climate change on the outbreak of infectious disease among children in Bangladesh: it's prenvetion and control

Outbreak Investigation Form: Line listing of Measles like cases

গ্রাম/মহল্লাঃ

ইউনিয়নঃ

অনুসন্ধানের তারিখঃ

হামের আউটব্রেক আইডেন্টিফিকেশন নাম্বারঃ

ওয়ার্ডঃ

জিলা/সিটি কর্পোরেশনঃ

অনুসন্ধানেকারী নামঃ

ক্রমিক নং	নাম	পিতার নাম	বয়স (মাস)	লিঙ্গ	রোগীর ঠিকানা (বাড়ির নং/জিআর নং/ফ্লাট নং, পাড়া/মহল্লা)	প্রাপ্ত হামের টিকার সংখ্যা (কার্ড /ইতিহাস)	হামের শেষ টিকা প্রাপ্তির তারিখ	জ্বরে আক্রান্ত হওয়ার তারিখ	দানা দেখা দেয়ার তারিখ	রক্ত রস সংগ্রহের তারিখ	জটিলতা (হ্যাঁ/না) যদি হ্যাঁ হয়, তবে উল্লেখ করুন, যেমন এআরআই, ডায়রিয়া, কানের সংক্রমন ইত্যাদি)	মৃত (হ্যাঁ/না) যদি হ্যাঁ হয়, তারিখ উল্লেখ করুন

Appendix-V
Rajshahi District
Upazila/Thana and Union/Ward with Geo-code 2011

Bagha Upazila
21- Arani Union
22 - Bajubagha Union
23 - Bausa Union
55 - Gargari Union
63 - Manigram Union
79 - Pakuria Union

Bagha Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Arani Paurashava
11 - Ward No - 01 12 - Ward No - 02 13 - Ward No - 03 14 - Ward No - 04 15 - Ward No - 05 16 - Ward No - 06 17 - Ward No - 07 18 - Ward No - 08 19 - Ward No - 09

Baghmara Upazila
20- Auch para Union
22- Bara Bihanali Union
24- Basupara Union
31- Dwippur Union
37-Goalkandi Union
44- Gobinda Para Union
50- Ganipur Union
56- Hamir Kutsha Union
63- Jhikra Union
69- Jogipara Union
72- Kachhari Kayali Para Union
75- Maria Union
82- Nardas Union
85- Sonadnaga Union
88- Sreepur Union
94-Subhadanga Union

Bhawbaniganj Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Tahirpur Paurashava
11 - Ward No - 01
12 - Ward No - 02 13 - Ward No - 03 14 - Ward No - 04 15 - Ward No - 05 16 - Ward No - 06 17 - Ward No - 07 18 - Ward No - 08 19 - Ward No - 09

Boalia Thana
09 - City Ward No - 09
10 - City Ward No - 10 (Part)
11 - City Ward No - 11 12 - City Ward No - 12 13 - City Ward No - 13
14 - City Ward No - 14 (Part)
15 - City Ward No - 15 16 - City Ward No - 16
18 - City Ward No - 18 (Part)
19 - City Ward No - 19 20 - City Ward No - 20 21 - City Ward No - 21 22 - City Ward No - 22 23 - City Ward No - 23 24 - City Ward No - 24 25 - City Ward No - 25 26 - City Ward No - 26
27 - City Ward No - 27 (Part)

Charghat Upazila
31 - Bhaya Lakshmipur Union
39 - Charghat Union 47 - Yusufpur Union 71 - Nimpara Union
87 - Salua Union
94 - Sardah Union

Charghat Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Durgapur Upazila
11 - Deluabari Union
23- Dharmapur (Pananagar) Union
35 - Jhaluka Union
47 - Joynagar Union
59 - Kismat Gankair Union
71 - Maria Union
83 - Noapara Union

Durgapur Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Matihar Thana
28 - City Ward No - 28
29 - City Ward No - 29 30 - City Ward No - 30

Mohanpur Upazila 13 - Bakshimail Union
27 - Dhurail Union
40 - Ghasigram Union 54 - Jahanabad Union 67 - Maugachhi Union
81 - Rayghati Union

Kesharhat Paurashava
01 - Ward No - 01 02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Paba Upazila
27 - Baragachhi Union
35 - Damkur Union
43- Darshan Para Union
51 - Haragram Union
54- Harian Union 61- Haripur Union
65 - Hujuri Para Union
87 - Parila Union

Katakhali Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Noahata Paurashava
11 - Ward No - 01 12 - Ward No - 02 13 - Ward No - 03 14 - Ward No - 04 15 - Ward No - 05 16 - Ward No - 06 17 - Ward No - 07 18 - Ward No - 08 19 - Ward No - 09

Puthia Upazila
13 - Baneshwar Union
27 - Belpukuria Union
40 - Bhalukgachhi Union
54 - Jeopara Union 67 - Puthia Union
81 - Silmaria Union

Puthia Paurashava
01 - Ward No - 01 02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Rajpara Thana
01 -City Ward No - 01
02 - CityWard No - 02 03 - CityWard No - 03 04 - CityWard No - 04 05 - CityWard No - 05 06 - CityWard No - 06 07 - CityWard No - 07 08 - CityWard No - 08
10- City Ward No – 10

Shah Mukhdun Thana
17 - City Ward No -17
18 - City Ward No -18 (Part)

94- Tanore Upazila 27 - Badhair Union
40-Chanduria Union
54 - Kalma Union
57 - Kamargaon Union 70 - Pachandar Union
77 - Saranjai Union 81 - Talanda Union

Tanore Paurashava
01 - Ward No - 01 02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Mundumala Paurashava
11 - Ward No - 01
12 - Ward No - 02 13 - Ward No - 03 14 - Ward No - 04 15 - Ward No - 05 16 - Ward No - 06 17 - Ward No - 07 18 - Ward No - 08 19 - Ward No - 09

Godagari Upazila 22 - Basudebpur Union
25 - Char Ashariadaha Union
28 - Deopara Union 38 - Godagari Union 47 - Gogram Union 57 - Matikata Union
66 - Mohanpur Union
76 - Pakri Union
85 - Rishikul Union

Godagari Paurashava
01 - Ward No - 01
02 - Ward No - 02 03 - Ward No - 03 04 - Ward No - 04 05 - Ward No - 05 06 - Ward No - 06 07 - Ward No - 07 08 - Ward No - 08 09 - Ward No - 09

Kakanhat Paurashava
11 - Ward No - 01
12 - Ward No - 02 13 - Ward No - 03 14 - Ward No - 04 15 - Ward No - 05 16 - Ward No - 06 17 - Ward No - 07 18 - Ward No - 08 19 - Ward No - 09

Appendix-VI
Naogaon District
Upazila and Union/Ward with Geo-code 2011

Atari Upazila
10-Ashanganj Union
21-Bhopra Union
31-Bisha Union
42-Hatkalupara Union
52-Kalikapur Union
63-Maniari Union
73-Panchupur Union
84-Sahagola Union

Badalgachhi Upazila
10-Adhaipur Union
21-Badalgachhi Union
31-Balubhara Union
42-Bilasbari Union
52-Paharpur Union
63-Kola Union
73-Mathurapur Union
84-Mithapur Union

Dhamoirhat Upazila
10-Agradigun Union
21-Alampur Union 31-Aranagar Union
42-Dhamoirhat Union
52-Isabpur Union
63-Jahanpur Union
77-Khelna Union
84-Omar Union

Dhamoirhat Paurashava
01-Ward No.01
02-Ward No.02 03-Ward No.03 04-Ward No.04 05-Ward No.05 06-Ward No.06
07-Ward No.07 08-Ward No.08 09-Ward No.09

Manda Upazila
12-Bhalain Union
13-Bharso Union
20-Bishnupur Union 27-Ganeshpur Union 33-Kalikapur Union 40-Kansopara Union
47-Kahab Union
54-Kusumba Union
61-Marani Union 67-Manda Union
74-Nurullabad Union
81-Paranpur Union 88-Parsadpur Union
94-Tentulia Union

Mahadebpur Upazila
15-Bhimpur Union
19-Chandas Union
28-Cheragpur Union 38-Enayetpur Union
47-Hatur Union
57-Khajur Union
66-Mahadebpur Union
76-Roygaon Union 85-Safapur Union
95-Uttargram Union

Naogaon Sadar Upazila
13-Baktiarpur Union
14-Balihar Union
21-Barshail Union
29-Boalia Union
36-Sailgachhi Union 43-Chandipur Union 51-Dubalhati Union
58-Hapania Union
65-Hashaighari Union
73-Kirtipur Union
87-Sekherpur Union
94-Tilakpur Union

Naogaon Paurashava
01-Ward No.01
02-Ward No.02 03-Ward No.03 04-Ward No.04 05-Ward No.05 06-Ward No.06
07-Ward No.07 08-Ward No.08 09-Ward No.09

Niamatpur Upazila
10-Bahadurpur Union
21-Bhabicha Union
31-Chandannagar Union
42-Hazinagar Union 52-Niamatpur Union
63-Parail Union
73-Rasulpur Union
84-Sreemanatpur Union

Patnitala Upazila
12-Akbarpur Union
17-Amair Union
25-Dibar Union
34-Goshnagar Union
43-Krishanapur Union
51-Matindhar Union
60-Nazipur Union
69-Nirmail Union
77-Patichara Union
86-Patnitala Union
94-Shihara Union

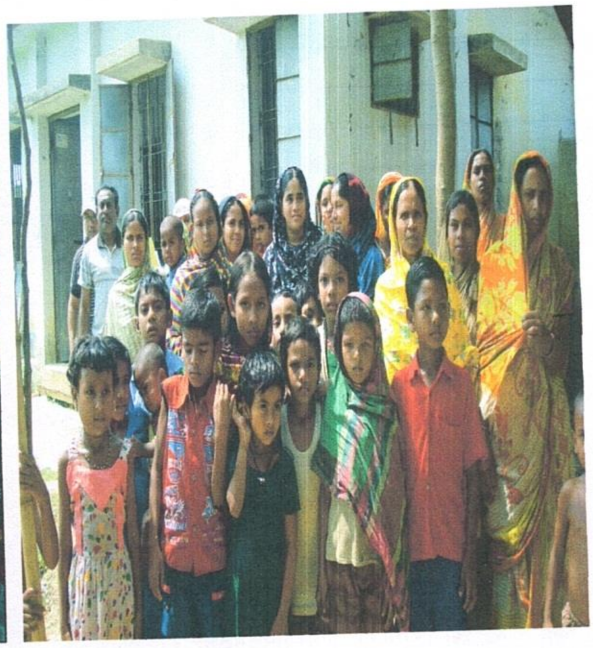
Patnitala Paurashava
01-Ward No.01
02-Ward No.02
03-Ward No.03
04-Ward No.04
05-Ward No.05
06-Ward No.06
07-Ward No.07
08-Ward No.08
09-Ward No.09

Porsha Upazila
15-Chhaor Union
23-Ganguria Union
31-Ghatnagar Union
47-Masidpur Union
55-Nithpur Union
87-Tentulia Union

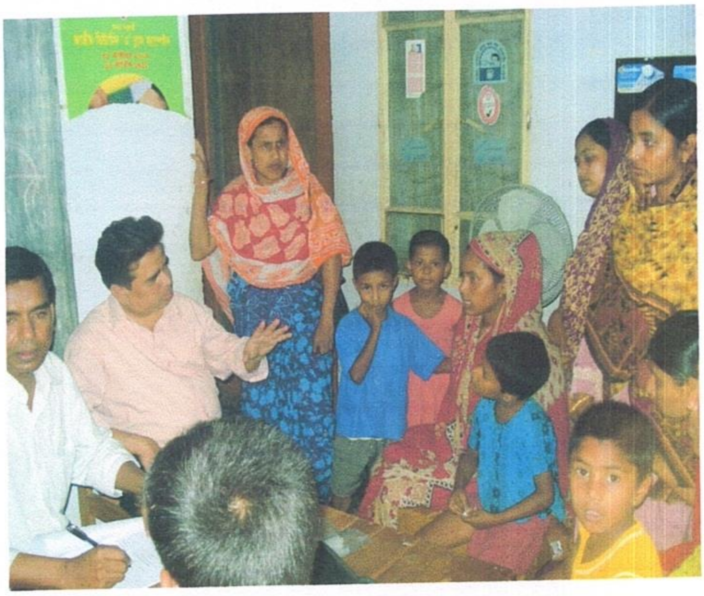
Raninagar Upazila
10-Bargachha Union
21-Ekdala Union
31-Gona Union
42-Kaligram Union
52-Kashimpur Union
63-Mirat Union
73-Parail Union
84-Raninagar Union

Sapahar Upazila
17-Aihai Union
39-Goala Union
63-Pathari Union
71-Sapahar Union
79-Shiranti Union
94-Tilna Union

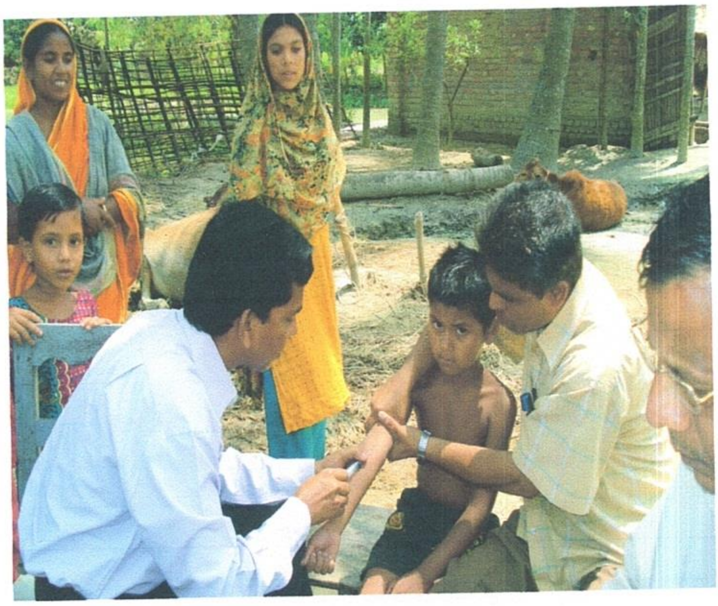
Interviewing mother regarding infectious disease and climate change knowledge in community household and clinic setup.



Interview mother about the outbreak of disease.



Collection of blood sample from patient in the community.



Interviewing mother regarding vaccination status of the children