An Analysis of the Impacts of Temperature on Diarrheal Disease in Bangladesh

COURSE TITLE: **Supervised Research Paper**

COURSE CODE: **Eco 495**

SEMESTER: **Spring 2014**

SUBMITTED TO:

Dr. A.K Enamul Haque

Professor

Department of Economics

East West University

SUBMITTED BY:

NAME: **Ehsanur Rauf Prince**

ID: **2010-2-30-019**

Submitted in partial fulfillment of the requirement for the award of Bachelor of Social Science in Economics Degree

Copyright Statement

Student Permission

Supervisor Permission

Name: ____

Date:

Signature:

Acknowledgements

First and foremost, I would like to express my gratitude to Allah, for blessing me with the ability to complete my thesis successfully. I am grateful to my parents for their supports. I sincerely acknowledge the role of my honorable teacher and thesis supervisor Prof. Dr. A. K. Enamul Haque for his valuable guidance in the writing of the thesis. I thank him, most of all, for his patience while the thesis was taking shape. Finally, the rest of the bachelor's cohort, both students and staffs, I thank them for making my undergraduate life enjoyable and academically productive.

Abstract

This thesis analyses the impacts of temperature on diarrheal disease in Bangladesh using district wise monthly average temperature and diarrhea (affected) data from Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review and World Food Programme (WFP) (1998-2010). Generalized Least Square (GLS) is used as estimation method is used to see whether temperature has impact on the number of diarrhea patients in Bangladesh and Optimization method is used to find maximum and minimum temperatures where diarrhea patients are found maximum and minimum respectively. Using results of the study, precautions and steps can be taken to minimize number of affected people due to diarrhea in the diarrhea-prone months.

Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1. Introduction

Diarrhea is one of the primary causes of morbidity and mortality on a global scale, with the major of deaths occurring in children under five years (Pruss-Ustun & Corvalan, 2007). It is a big problem in developing countries (Zhao et al., 2012). Diarrhea has been linked to climate mediated changes for susceptible populations such as infants and the elderly who often have relatively poor immunity (Partz , Lendrum , Holloway & Foley , 2005).

According to the United Nations Children's Fund (UNICEF) and World Health Organization (WHO) (2009), diarrhea is a common symptom of gastrointestinal infections caused by a wide range of pathogens including bacteria, viruses and protozoa. Rotavirus is the leading cause of acute diarrhea, and is responsible for about 40 percent of all hospital admissions due to diarrhea among children under five worldwide.

There are three main forms of acute childhood diarrhea-Acute water diarrhea, Bloody diarrhea and Shigella. Acute watery diarrhea includes cholera and is associated with significant fluid loss and rapid dehydration in an infected individual and usually lasts for several hours or days. Bloody diarrhea, often referred to as dysentery, is marked by visible blood in the stools. The most common cause of bloody diarrhea is Shigella, a bacterial agent that is also the most common cause of severe cases (UNICEF &WHO, 2009).

According to the WHO and UNICEF, there are about two billion cases of diarrheal disease worldwide every year, and 1.9 million children younger than 5 years of age perish from diarrhea each year, mostly in developing countries. This amounts to 18% of all the deaths of children under the age of five and means that more than 5000 children are dying every day as a result of diarrheal diseases. Of all child deaths from diarrhea, 80% occur in the African and South-East Asian regions. (Figure1). Three quarters of global childhood diarrheal deaths occur within only 15 countries and Bangladesh is in 7th position with 50,800 annual childhood deaths (Table1).Systematic surveillance in two rural health facilities between August 2005 and July 2007 among under-5 children revealed that 12-14% cases of hospitalization in rural Bangladesh were due to rotavirus infection. Moreover, prevalence of shigellosis fell from 8-12% from 1980 to 3% in 2008, amongst diarrheal disease patients in a large facility in Dhaka, the capital city of Bangladesh (Das et al., 2013).

This research is divided into nine chapters. Chapter one gives introduction while the second chapter mentions objectives of the research. Literature reviews on previous studies related to the research have been discussed in chapter three and four. Chapter five provides methodology which deals with sources of data and analytical techniques for this research. Chapter six discusses results obtained from the research. Chapter seven draws relevant conclusions. Chapter eight contains references while chapter nine contains appendix.

CHAPTER 2: OBJECTIVES

2. Objectives

2.1. General Objective

To find out whether change in temperature has any impact on the number of diarrhea patents in Bangladesh.

2.2. Specific Objective

If temperature has any impact on the number of diarrhea patients, then an attempt will be made to find out the maximum and minimum temperatures where numbers of diarrhea patients are found maximum and minimum respectively.

CHAPTER 3: LITERATURES on DIARRHEAL DISEASE and IMPACTS of

TEMPERATURES on DIARRHEAL DISEASE

3. Literatures on Diarrheal Disease and Impacts of Temperature on Diarrheal Disease

3.1. Literature on Diarrheal Disease

Diarrhea is usually a symptom of an infection in the intestinal tract which can be caused by a variety of bacterial, viral and parasitic organisms (WHO, 2013). Armon, Stephenson, Macfaul, Ecclesston & Werneke (2011) defined diarrhea as a change in bowel habit which results in more frequent or looser stools. Though some diarrheas are due to errors of metabolism, chemical irritation or organic disturbance, the vast majority are caused by infectious pathogens (Gracy, 1985).

Usually diarrhea is caused by enteric bacterial infections and found worldwide, especially in tropical and developing countries among older children and adults. The ranges of causative micro organisms are very large; they include E. coli, Salmonella, Shigella, Campylobacter, Yersinia, vibrios, and Clostridium difficile (Gracy, 1996).

Rotavirus is one of the most common causes of severe diarrhea. Other viruses also play role for diarrheal disease in human, including Norwalk virus, Norwalk-like viruses, enteric adenoviruses, caliciviruses, and astroviruses (Gracy,1996). Parasites can enter the body through food or water and settle in the digestive system. Parasites that cause diarrhea include Giardia lamblia, Entamoeba histolytica, Cyclospora cayetanensis and Cryptosporidium (Hung, 2006).

3.2. Impacts of Temperature on Diarrheal Disease

According to Xu, Liu , Ma, Toloo , Hu and Tong (2014) , both heat and cold are associated with increases in emergency department visits (EDVs) for childhood diarrhea which may be partially explained by three reasons. First, high temperature may impact the food chain, from food preparation stage to production process and expose children to more contaminated food. Second, low temperature increases the replication and survival of virus, e.g. , rotavirus . Third, extreme low and high temperatures may alter children's hygiene behavior such as water drinking behavior.

According to D'Souza, Hall and Becker (2007), Rotavirus can remain viable outside the human body from several hours to several months, depending on the environment. The ideal environment for survival of rotavirus consists of low temperature (4- 20°C), low pH (~3), low humidity and protection from ultraviolet radiation. In feces, rotavirus is found to be stable at low and high relative humidity but not in the medium range of relative humidity. Rotavirus infectivity is lost more rapidly at 37°C than at 4°C or 20°C. Even at ambient temperatures above 30°C rotavirus particles stored in feces are stable and may infectious in vitro after 2-5 months of storage.

Seasonal pattern of rotavirus infections may be related to climatic factors. Cold and dry weather have been associated with a higher number of rotavirus gastroenteritis hospital admissions, suggesting weather related increases in exposure to rotavirus infection. Indoor relative humidity has also been speculated to be an important factor for young infants. Rotavirus infection has been reported to occur more in the dry season compared to the wet season in African countries like Morocco, Algeria, Egypt, Bangladesh, India and Costa Rica (D'Souza, Hall and Becker ,2007).

3.3. Literature on Diarrheal Epidemics in Bangladesh

Diarrhea is very much related to sanitation, water, high population density, cleanliness and vector borne diseases in Bangladesh. Flood makes water sources contaminated and scarce. Children are mainly affected with diarrhea as many of them swim in the dirty flood waters to fetch relief item and some of the young children play in the dirty water out of boredom- even drink and bath on it

(Khan, 2010). Most of the educational institutions, hospitals, offices, bus stoppages and railway stations do not have clean wash rooms. Major portion of Bangladeshis take food with hands without help of sterilized knife, fork or spoon. This imposes the risk of incidence of diarrhea due to taking food by using unclean hands.

Flood-related diarrheal epidemics cause significant morbidity and mortality in Bangladesh (WHO, 2003). During the 1988 flood in Bangladesh, diarrheal disease was responsible for 35% of all flood-related illness and 27% of 154 flood-related deaths in a population of more than 45,000 patients in rural Bangladesh (Siddiqu, Baqui, Eusof & Zaman, 1998). During the 1998 flood period, 25% of 3,109 people surveyed in two rural areas of Bangladesh reported diarrheal illness (Kunni, Nakamura, Abdur & Wakai, 1998).

Extreme temperature and decayed food also causes high prevalence of diarrheal diseases especially among children under five in Bangladesh (Khan et al., 2010). In the 1970s, the infant mortality rate attributable to diarrhea was up to 36 per 1000 live births and accounted for a significant proportion of total infant mortality (140/1000) (Bern, Martines, Dezoysa & Glass, 1992). Although diarrhea is still one of the leading causes of childhood mortality, the number of deaths attributed to diarrhea has decreased markedly down to 13 per 1000 infants out of a total infant mortality of 65 per 1000 live births. (Wu et al., 2012).

In recent years Dhaka City is facing extensive water logging during the monsoon (May to October) which has become a common and regular problem of the city. In Dhaka, 58.7% are poorly drained (CUS, 2005). Slum settlements are often found on land which is in most cases unsuitable for proper housing. For instance, low lying areas, marshes, sewage canals, riversides, railway tracts and embankments are frequently the site of slums. These sorts of places are prone to suffer from poor drainage and hence water logging (stagnation of water) particularly during the rainy season (Khan, 2010).

Major portion of the slum dwellers (60%) use pit or hanging latrines and 85% throw their daily waste haphazardly. Those pit and hangings latrine are connected to the ditches and canals. As a result both household waste and human generated wastes go directly or indirectly into the low-lying lands, open spaces or water bodies of the city and causes a number of health problems including diarrhea (Khan, 2010).

In tertiary-level public hospitals in Bangladesh, there is ample opportunity for infection transmission through the fecal–oral route. (Bhuiyan et al., 2014).The number of admitted patients frequently exceeds the number of available beds. Patients often share beds or are cared for on the floor. As a result of inadequate critical care units, patients with severe illnesses such as acute respiratory infection, cardiovascular disease, and stroke are often treated in the same general medicine wards where diarrheal patients are also treated (Gurley et al., 2010). Most patients have at least one personal caregiver, usually a family member, who provides the majority of hands-on care that nursing staff would typically provide in high-income countries (Zaman, 2004). Hand washing stations often lack soap and constant water supply (Rimi et al.,2012). Moreover, limited routine infection control in crowded wards, lead to situations where patients are at high risk of being infected by contaminated food, water, and hospital surfaces and also during contact with other patients, caregivers, and healthcare workers (Pittet et al., 2008 ; Sanderson & Weissler, 1992).

CHAPTER 4: LITERATURES ON ESTIMATION METHOD

4. Literature on Estimation Method

Teshima, Yamada , Hayashi, Wagatsuma and Terao (2004) applied Empirical Orthogonal Function (EOF) analysis method to time series of diarrhea patients and meteorological elements in Bangladesh to understand effects of the meteorological variation to the prevalence of the diarrhea disease. They took averages every two weeks in each year from 1981 to 2001. That is, yearly data were divided into 26 portions and each portion contained 22 data for 22 years. The patient data are normalized by the yearly total patient number to remove the year to year increasing trend. Two types of correlation analysis were carried out for meteorological elements and patient number- a) lag correlation of meteorological elements to one fixed portion of patient and b) lag correlation of patient number to one fixed portion of meteorological elements. The *i*th portion in *w*th year is expressed as *X(w,i)* for patient data and *Y1(w,i)~Y4(w,i)* for meteorological elements. EOF analysis was applied to *X(w,i)~Y4(w,i)* by correlation matrix of the anomaly $x_i(w) = X(w, i) - (i)$ and $y_i(w) = Y(w, i) – (i)$ where *(i)* and *(i)* are averages on *i*. The seasonal variation of the diarrhea patients showed two peaks in the pre-monsoon (March and April) and at the end of the monsoon (September and October). The EOF analysis of the time series of patients and meteorological elements showed that in the dominating component, the anomaly of the number of the diarrhea patients had different signs for the periods before and after June, corresponding to the two peaks of the averaged number of the patients. Higher maximum temperature and more sunshine in the pre-monsoon period were found to have a tendency to enhance the first peak of the diarrheal occurrence.

Chou ,Wu, Wang, Huang , Sung and Chuang (2010) investigated and quantified the relationship between climate variations and diarrhea-associated morbidity in subtropical Taiwan. Their study applied a climate variation- guided Poisson regression model to predict the dynamics of diarrhea-associated morbidity. The regression mode was described as:

Here denotes the incidence of diarrhea confirmed cases at time t, through individually represent the coefficients, and , and RH are the monthly maximum temperatures (°C), the extreme rainfall intensity (mm) and the relative humidity (%) respectively. The term t-n in the subscript represents the n- month lag time. The model includes lag values to control for the autocorrelation of explanatory variables. To consider how seasonality and long-term trends may be associated with weather conditions, the model included a triangular function sin to reveal the seasonality component in series. Study results indicated that the maximum temperature and extreme rainfall days were strongly related to diarrhea-associated morbidity. The impact of maximum temperature on diarrhea-associated morbidity appeared primarily among children (0-14years) and older adults (40-64years) but had less of an effect on adults (15-39years).

Kolstad and Johansson (2011) combined a range of linear regression coefficients to compute projections of future climate change-induced increases in diarrhea using the results from previous empirical studies. Data from 19 coupled atmosphere–ocean climate models from the World Climate Research Programme Coupled Model Intercomparison Project Phase 3 (CMIP3) multimodel data set (Meehl et al. 2007) were used to form a large multimodel ensemble. They analyzed six geographical regions- South America, North Africa, Middle East, equatorial Africa, Southern Africa and Southeast Asia. The model ensemble projected temperature increases of up to 4°C over land in the tropics and subtropics by the end of this century. The associated mean projected increases of relative risk of diarrhea in the six study regions were 8–11% by 2010–2039 and 22–29% by 2070–2099.

Bandari, Gurung , Dhimal and Bhusal (2012) made a retrospective study in Nepal where data of past ten years relating to climate and disease (diarrhea) variable were analyzed. The study conducted trend analysis based on correlation. Time series analysis was also being conducted. Statistically significant correlation between diarrheal cases occurrence and temperature and rainfall had been observed in their study.

Alexander, Carzolio, Goodin and Vance(2013) evaluated monthly reports of diarrheal disease among patients presenting to Botswana health facilities and compared this to climatic variables using health data from Bostwana spanning a 30-year period (1974-2003). They analyzed monthly diarrhea against predictor variables using an autoregressive analysis of covariance model. The analysis included monthly average national rainfall, vapor pressure, inverse vapor pressure (1/q), a dummy variable indicating wet or dry season, temperature variables and minimum temperature divided by vapor pressure (Tmin/q). Dealing with socioeconomic variation over time can add an important amount of complexity to the analysis of long-term time series data. To minimize potential reporting biases associated with these changes and other potential confounding variables, the analyses was done by standardizing monthly diarrheal data on a yearly basis, transforming the data as follows:

where is defined as the monthly proportion deviation from the mean number of cases of diarrhea for month *m* in year *y*, is the number of reported cases of diarrhea in month *m* of year *y*, and is the mean number of monthly cases of diarrhea for year *y*. Diarrheal case incidence presented with a bimodal cyclical pattern with peaks in March and October in the wet and dry season, respectively. It was found that there were strong positive autocorrelation in the number of reported diarrhea cases at the one-month lag level. Climatic variables (rainfall, minimum temperature, and vapor pressure) predicted seasonal diarrheal with a one-month lag in variables. Diarrheal case incidence was highest in the dry season after accounting for other variables, exhibiting on average a 20% increase over the yearly mean.

Xu , Huang, Turner, Su, Qiao and Tang(2013) used a Poisson generalized linear regression model combined with a distributed lag non-linear model (DLNM) to examine the relationship between diurnal temperature range and emergency department admissions for diarrhea among children under five years in Brisbane, from 1st January 2003 to 31st December 2009. Akaike Information Criterion (AIC) and analysis of residuals were used to evaluate the model fit and choice of *df*.

Where t is the day of the observation, Y_t is the observed daily childhood diarrhea on day t and α is the model intercept. $DTR_{t,l}$ is a matrix obtained by applying the DLNM to DTR, β is vector of coefficients for $DTR_{t,l}$ and l is the lag days. The terms $ns(T_t,\ 3)$ and $ns(RH_t,\ 3)$ are natural cubic splines with three degree of freedom which control for mean temperature and relative humidity respectively. To control for long term trends, a natural cubic spline $ns(Time_t, 6)$ with six degrees of freedom was incorporated. DOW_t is the categorical day of the week with a reference day of Sunday. A statistically significant relationship between diurnal temperature range and childhood diarrhea was found in the study . The effect of diurnal temperature range on childhood diarrhea was the greatest at one day lag, with a 3%

increase of emergency department admissions per 1°C increment of diurnal temperature range.

CHAPTER 5: DATA AND METHODOLOGY

5. Data and Methodology

5.1. Sources of Data

Based on the objectives of the study, district wise monthly average temperature and Diarrhea (affected) data from the year 1998 to 2010 have been used in the study. Data were secondary in nature and were collected from the reports of Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review and World Food Programme (WFP).

5.2. Analytical Technique

Gujrati (2004) defined heteroscedasticity as when the error terms (U_is) do not have same variance (which violates one of the OLS assumptions that the variances of U_is will be same for all values of the explanatory variables. Symbolically,

In this research Breusch-Pagan-Godfey test was used for the detection of heterscedasticity in the model. According to Gujarati (2004), to understand the basic idea behind Breusch-Pagan-Godfey test, first a *k*-variable linear regression model is considered:

where , , and are regressand, intercept, slope coefficient and error terms respectively.

Assuming the error variance is described as

that is, is some function of the nonstochastic variables Z's; some or all of the X's can serve as Z's. Specifically the following equation has been assumed:

that is, is a linear function of the Z's. If which is a constant. Therefore, to test whether is homosceadastic, one can test the hypothesis that .

To overcome the problem of heteroscedasticity of the Ordinary Least square Method (OLS), Generalised Least Square (GLS) method has been used in the research as the estimation method. According to Gujarati (2004), GLS method takes the criteria into account that observations which come from populations with greater variability are given less weight than those come from populations with smaller variability and therefore capable of producing estimators which are BLUE (Best Linear Unbiased Estimators). First, a two variable mode will be taken under consideration.

where , ,and are regressand, intercept, slope coefficient and error term respectively. (*i*=1, 2, 3….. n)

For the ease of algebraic manipulation the above equation can be written as:

where for each *i* . Assuming heteroscedastic variances (are known and dividing equation (2) by , the following equation is obtained:

For the ease of exposition the above equation can be written as:

where the starred or transformed variables are the original variables divided by (known) . The notations and illustrates the parameters of the transformed model which distinguished the OLS parameters and .

In this research optimization method has been used to find maximum and minimum temperature where the number of diarrhea patients is found maximum and minimum respectively. According to Chiang and Wainwright (2005) the derivative function measures the rate of change of the function . By the same token, the second-derivative function is the measure of the rate of change of the first derivative ; in other words, the second derivative measures the rate of change of the rate of change of the original function . To put it differently, with a given infinitesimal increase in the independent variable from a point ,

means that the value of the function tends to

Whereas, with regard to second derivative,

means that the slope of the curve tends to

Thus a positive first derivative coupled with a positive second derivative at implies that the slope of the curve is positive and increasing. In other words, the value of the function is increasing at an increasing rate. Likewise, a positive first derivative with a negative second order derivative indicates that the slope of the curve is positive but decreasing- the value of the function is increasing at a decreasing rate.

Using the above theories mentioned above, a cubic equation has been developed to find out impacts of temperature on diarrheal disease in Bangladesh.

……….. (1)

Where, Y is the number of diarrhea patients, *C* is Constant term, is the regression coefficients to be estimated (i=1,2,…,6), T is temperature, is temperatures less than 15 degree Celsius, is temperatures greater than 25 degree Celsius , Trend= Year-1998 (Year=1998,1999,…..2010) and is random error.

CHAPTER 6: RESULTS AND DISCUSSION

6. Results and Discussion

6.1 Analysis of Descriptive Statistics

Using district wise monthly average temperature and diarrhea (affected) data from 1998-2010, descriptive statistics on temperature and diarrhea patients are presented in table 2 and 3 respectively.

It is observed that monthly average temperature is minimum in January (17.73 degree Celsius). After January temperature increases and reaches maximum in June (28.75 degree Celsius). After June temperature starts to decrease (Table 2 and Figure 2).

Table -2. Descriptive Statistics on Temperature from 1998 to 2010

Month	Average temperature in Celsius	Standard deviation	Variance	Skewness	Kurtosis
January	**17.73**	0.87	0.77	-0.36	-0.47
February	21.44	1.05	1.10	0.32	0.77
March	25.48	1.01	1.02	-0.30	-0.33
April	28.21	0.81	0.65	0.37	-0.78
May	28.68	0.59	0.35	-0.27	-0.98
June	**28.75**	0.62	0.38	0.71	-0.55
July	28.47	0.32	0.10	0.63	-0.24
August	28.65	0.34	0.12	-0.04	-0.37
September	28.35	0.32	0.10	-0.78	-0.36
October	27.22	0.45	0.20	0.28	0.23
November	23.71	0.59	0.35	0.24	0.37
December	19.60	0.51	0.04	0.04	-1.52

From table 3 it is observed that in the year 2002, 1.97 percent of total population got affected with diarrhea. Between the years 1998 to 2010, two major floods occurred in Bangladesh (1998 and 2004). Share of population got affected with diarrheal disease in 1998 and 2004 were 1.63

and 1.65 respectively. Between the years 1998 to 2010, share of population got affected with diarrhea was minimum in 2000 (1.20 percent).

Table -3. Descriptive Statistics on % of Population Diarrhea Affected 1998-2010

Year	% of Population Diarrhea Affected
1998	1.63
2000	**1.20**
2001	1.44
2002	**1.97**
2003	1.71
2004	1.65
2005	1.56
2006	1.40
2007	1.65
2008	1.60
2009	1.79
2010	1.64

Source: Bangladesh Economic Review (2014) & WFP

6.2. Estimated Results

Table 4 shows the estimated results obtained from GLS.

Table -4. Estimated Results using Generalized Least Square Method (GLS)

Dependent variable: Number of diarrhea affected patients; Number of observations: 1170;
Number of groups: 26; Observations per group: min=31, average=45,max=47;
: within=0.0569, between=0.0919, overall= 0.0456;
=40.32; prob > =0.0000

	Co-efficient	**Robust Std. Err**	**Z**	**p>|z|**
T	37189.65*	8408.024	4.42	0.000
	-1624.502*	363.3851	-4.47	0.000
	22.68555*	5.06424	4.48	0.000
	268.249	176.0303	1.52	0.128
	158.3958*	40.20512	3.94	0.000
Trend	232.569*	66.94804	3.47	0.001
C	-268081.9*	62554.38	-4.29	0.000

***Significant at 95% Confidence Interval**

From Equation (1) and the estimates of the regression model the following equation is obtained.

From the equation, it is observed that except , remaining variables (*T,* , , , Trend and C) are significant at 95% confidence level. As per rule of optimization (solving the equation by setting first differentiation equals zero) and letting =1, maximum and minimum value of temperature is found at 28.45 and 19.28 degree Celsius respectively.

By solving the equation by setting second order differentiation equals zero, the value of temperature is found at 23.86 degree Celsius.

These results mean that the number of people affected with diarrhea is found minimum at 19.28 degree Celsius temperature. Below and above 19.28 degree Celsius temperature, number of diarrhea patients increase. Above 19.28 degree Celsius temperature, number of diarrhea patient increases more than 37190 per one degree increase in temperature (increases at an increasing rate). This continues up to 23.86 degree Celsius temperature. After 23.86 degree Celsius temperature, number of diarrhea patient increases less than 37190 per one degree increase in temperature (increases at a decreasing rate). At 28.45 degree Celsius number of diarrhea patient is found maximum. After 28.45 degree Celsius temperature, number of diarrhea patients starts to decline.

According to Xu, Liu , Ma, Toloo , Hu and Tong (2014) , high temperature may impact the food chain, from food preparation stage to production process and expose children to more contaminated food. Low temperature increases the replication and survival of virus, e.g., rotavirus. These could be reasons why below and above 19.28 degree Celsius temperature number of diarrhea patients increase. Extreme temperatures (high and low) also may alter people's hygiene behavior. Bangladeshi rural households have restricted access to medical service and have poor housing conditions. (Ahmed, 2004; Practical Action ,2010; UNICEF, 2010). This may trigger or exacerbate their existing health problems.

CHAPTER 7: CONCLUSION

7. Conclusion

This thesis analyzed the impact of temperature on diarrheal disease in Bangladesh using data from Bangladesh Bureau of Statistics (BBS) and World Food Programme (WFP) (1998-2010). Generalized Least Square (GLS) is used as estimation method and Optimization method is used to find maximum and minimum temperatures where diarrhea patients are found maximum and minimum respectively in Bangladesh. Results of the thesis show that maximum and minimum temperatures are found at 19.28 and 28.45 degree Celsius respectively. Also it is found that between 19.28 and 23.86 degree temperatures, with an increase in temperature, diarrhea patient increases at an increasing rate and after 23.86 degree

Celsius temperature, with an increase in temperature, diarrhea patient increases at a decreasing rate. This continues up to 28.45 degree Celsius temperature.

Results of the study can be used to make precautions and help to take steps to minimize number of affected people due to diarrhea in the diarrhea-prone months. Different non government organizations, international organizations and Government of Bangladesh have been taking multifaceted and multidimensional activities in this regard. However, their awareness, prevention and treatment activities for diarrhea should be scaled up to minimize mortality and morbidity due to diarrhea in diarrhea prone months in Bangladesh.

CHAPTER 8: REFERENCES

8. REFERENCES

Abram, S.B. (1995). Control of Communicable diseases Manual. *American Public Health Association.* 16. 250-254.

Adkins, H.J., Escamilla, J., Santiago, L.T., Ranoa, C., Echeverria, P. & Cross, J.H.(1987). Two-year Survey of Etiologic Agents of Diarrheal Disease at San Lazaro Hospital, Manila, Republic of the Philippines. Journal of Clinical Microbiology. 25. 1143–1147.

Ahmed, AH. (2009). Adaptations to Climate Change in Bangladesh.

Armon, K., Stephenson, T., MacFaul, R., Eccleston, P., Werneke, U. (2001). An Evidence and Consensus based Guideline for Acute Diarrhoea Management.Archives of Disease in Childhood. 85. 132-42.

Bandari, G.P., Gurung, S., Dhimal, S., & Bhusal, C.L. (2012). Climate Change and Occurrence Diarrheal Diseases: Evolving Facts from Nepal. *J Nepal Health Res Counc*. 10(22). 181-186.

Banerjee ,B., Hazra, S. & Bandyopadhyay, D. (2003). Diarrhea Management Among Under Fives.*Institute of Hygiene and Public Health, India.* Retrieved from http://www.indianpediatrics.net/mar2004

Bern, C., Martines, J., Dezoysa, I. & Glass, R.I. (1992). The magnitude of the global problem of diarrheal disease - a 10-year update. *Bulletin of the World Health Organization.* 70. 705–714.

Bentham, G. & Langford, I.H. (1995).Climate Change and the Incidence of Food Poisoning in England and Wales. *International Journal of Biometeorology*. 39. 81–86.

Bentham, G. & Langford, I.H. Environmental Temperatures and the Incidence of Food Poisoning in England and Wales. *International Journal of Biometeorology.* 45. 22–26 .

Bhuiyan, M.U., Luby, S.P., Zaman, R., Rahman, MW, Sharker, M.A.Y,…Gurley ES. (2014). Incidence of and Risk Factors for Hospital-Acquired Diarrhea in three Tertiary Care Public Hospitals in Bangladesh. The *American Journal of Tropical Medicine and Hygene.* 91. 165-72. Retrieved from http://www.ajtmh.org/content/91/1/165.full

Brooks, J.T.,Sharpiro RL, Kumar, L., Wells, P.G., Phillip-Howard, P.A., Shi, Y.P., …Slutsker L.(2003). Epidemiology of Sporadic Bloody Diarrhea in Rural Western Kenya. *The American Journal of Tropical Medicine and Hygene.* 2003. 68 . 671–677.

Centre for Urban Studies (CUS), 2005. Slums of urban Bangladesh, Mapping and Census.

Chiang ,A.C., & Wainwright, K.(2005). Fundamental Methods of Mathematical Economics. *McGraw Hill.*

Chou, W.C., Wu, J.L., Wang, Y.C., Huang H., Sung, F.C., & Chuang, C.Y. Modeling the Impact of Climate Variability on Diarrhea-Associated Diseases in Taiwan (1996-2007). (2010). *Science of Total Environment.* 409. 43-51.

Curtis, V., Cairncross, S. & Yonli, R. (2000). Review: Domestic Hygiene and Diarrhoea – Pinpointing the Problem. Tropical Medicine and International Health. 5 . 26–30.

D'Souza, R., Becker, N., Hall, G. & Moodie, K. (2004). Does ambient temperature affect foodborne disease? *Epidemiology.*15. 86–92.

D'Souza, R. M., Hall, G. & Becker, N. G. (2008). Climatic factors associated with hospitalizations for rotavirus diarrhoea in children under 5 years of age. *Epidemiology and Infection.* 136. 56–64.

Das, S.K., Ahmed, S., Ferdous, F., Farzana, F.D., Kaur ,G., … Faruque, A.S.G. (2013). Disease Severity and Common Etiology of Diarrhea among Children Under-five in Mirzapur, Rural Bangladesh. *The American Journal of Tropical Medicine and Hygene.* 89(2). 223–228.

Donaldson, G.C., Tchernjavskii V.E., Ermakov, S.P., Bucher K. & Keatinge W.R. (1998).

Winter Mortality and Cold Stress in Yekaterinberg, Russia: Interview survey. *British Medical Journal*. 316. 514–518.

Donaldson, G.C., Rintamaki H. & Nayha S.(2001). Outdoor Clothing and its Relationship to Geography, Climate, Behaviour and Cold Related Mortality. *International Journal of Biometeorology*. 45 .45–51.

Etiler, N., Velipasaoglu, S., Aktekin, M.(2004). Risk Factors for Overall and Persistent Diarrhea in Infancy in Antalya, Turkey. *Public Health*. 118. 62-69.

Gascon, J., Vargas, M., Schellenberg, D., Urassa, H., Casals, C., Kahigva, E., Aponte, J.J., Mshinda, H. & Vila, J. (2000). Diarrhea in Children under 5 Years of Age from Ifakara, Tanzania. Journal of Clinical Microbiology. 38 . 4459–4462.

Ghosh, S., Sengupta, P.G., Mondal, S.K., Banu, M.K., Gupta, D.N. & Sircar, B.K. (1997). Risk Behavioural Practices of Rural Mothers as Determinants of Childhood Diarrhoea. *Journal of Communicaiton Disorders*. 29 .7-14.

Gorter, A.C., Sandiford, P., Pauw, J., Morales, P., Perez, R.M. & Alberts, H. (1998). Hygiene Behaviour in Rural Nicaragua in Relation to Diarrhoea. *International Journal of Epidemiology*. 27.1090-1100.

Gracey M. (1985). Diarrhoeal Disease and Malnutrition. *Churchill Livingstone, Edinburgh*.

Gracey M. (1996). Diarrhea and Malnutrition: A Challenge for Pediatricians. *J Pediatr Gastroenterol Nutr*. 1996. 22. 6-16.

Gujarati, DN.(2004). Basic Econometrics.*McGraw Hill.*

Gurley, E.S., Zaman, R.U.,Sultana, R., Bell, M.,Srinivasan, A.,Rahman, M.,…Luby, S.P. 2010. Rates of hospital-acquired respiratory illness in Bangladeshi tertiary care hospitals: results from a low-cost pilot surveillance strategy. *Clinical Infectious Diseases.* 50. 1084-1090.

Hales, S., Edwards, S.J. & Kovarts, R.S. (2014) Impact on Heath of Climate Extremes. Retrieved from http://www.who.int/globalchange/publications/climatechangechap5.pdf

Hung BV. (2006). The Most Common Causes of and Risk Factors for Diarrhea among Children less than Five Years of Age Admitted to Dong Anh Hospital, Hannoi, Northern Vietnam. *Department of General Practice and Community Medicine, University of Oslo, Norway.* Retrieved from https://www.duo.uio.no/bitstream/handle/10852/30133/HungxBui.pdf?sequence=2

IPCC .(2007).Climate Change 2007: The Physical Science Basis. In: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*.

Jane, S. H. & Swanson, L.N. (1995). Diarrhea. *Jobson Publication.* Retrieved from http://legacy.uspharmacist.com/oldformat.asp?url=newlook/files/Feat/ACF2EF8.cfm&pub_id=8&article_id=37

Jensen, P.K., Ensink, J.H., Jayasinghe, G., Hoek V.D.W., Cairncross, S & Dalsgaard, A. (2002). Domestic transmission routes of pathogens: the problem of in-house contamination of drinking water during storage in developing countries. *Tropical Medicine and International Health*. 7. 604–609.

Jensen, P.K., Jayasinghe, G. Hoek,V.D.W., Cairncross, S & Dalsgaard, A. (2004). Is there an association between bacteriological drinking water quality and childhood diarrhea in developing countries? *Tropical Medicine and International Health*.9. 1210–1215.

Jinadu, M.K., Olusi, S.O., Agun, J.I & Fabiyi, A.K.(1991). Childhood diarrhoea in rural Nigeria. *Journal oF Diarrhoeal Disease Research.* 9. 323-327.

Karim, A.S., Akhter, S., Rahman, M.A & Nazir, M.F. (2001). Risk factors of persistent diarrhea in children below five years of age. *Indian Journal of Gastroenterology*.20.59-61.

Kilbourne, E.M. Heat Waves. (1989). In: The public health consequences of disasters. Gregg, M.B. Atlanta, US, US Department of Health and Human Services, Centers for Disease

Control. 51–61.

Khan, A.N.M.M. (2010). Impact of Climate Change on the Livelihood of the Urban Poor. *Department of General and Continuing Education, North South University, Bangladesh.* Retrieved from http://mppg-nsu.org/attachments/119_Maruf_climate%20change.pdf

Kolstad, E.W., Johansson, K.A. (2011**).** Uncertainties Associated with Quantifying Climate Change Impacts on Human Health: A Case Study for Diarrhea. *Environmental Health Perspectives.* 119(3) . 299–305.

Kosek, M.., Bern, C. & Guerrant, R.L. (2003). The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. *Bull World Health Organ* . 81. 197-204.

Kunii, O., Nakamura, S., Abdur, R., & Wakai, S. (2002). The impact on health and risk factors of the diarrhoea epidemics in the 1998 Bangladesh floods. *Public Health.*116. 68–74.

Long, K., Vasquez-Garibay, E., Mathewson, J., de la Cabada, J. & DuPont, H.(1999). The Impact of Infant Feeding Patterns on Infection and Diarrheal Disease due to Enterotoxigenic Escherichia Coli. Salud Publica de Mexiuco. 41. 263-270.

Madico, G. Mc Donald, J., Gilman, R., Cabrera, L.& Sterling, C.R. Epidemiology and Treatment of Cyclospora Cayetenanis Infection in Peruvian Children. *Clinical Infectious Diseases*. 24. 977–981.

Marjatta, B.S. (1994).Water Supply and Diarrhea in East African Community: A Case- Control Study on the Quality of Water Supplies and the Occurrence of Diarrhea Among Small Children in a Rural Area of Western Kenya. *Department of Public Health Science and General Practice, University of Oulu, Finland*. 37-57.

Meehl, G.A., Covey, C., Delworth, T., Latif M., McAvaney, B., Mitchell, J.F.B, … Taylor, K.E. (2007) .The WCRP CMIP3 Multimodel Dataset: A New Era in Climate Change Research. *American Meteorological Society*. 88. 1383–1394.

Molbak, K, Jensen, H., Ingholt, L. & Aaby P.(1997). Risk Factors for Diarrheal Disease Incidence in Early Childhood: A Community Cohort Study from Guinea-Bissau. *American Journal of Epidemiology.*146.273-282.

Molbak, K.(2000). The epidemiology of diarrheal diseases in early childhood: A review of community studies in Guinea-Bissau. Department of Epidemiology Research, University of Copenhaghen. Retrieved from http://www.ssi.dk/pdf.ashx?title=K%C3%A5re-M%C3%B8lbak-&url=http%3A%2F%2Fwww.ssi.dk%2FForskning%2FForskningsafdelinger%2FAfdeling+for+Epidemiologisk+Forskning%2FAfhandlinger%2FKaare+Molbak.aspx%3Fpdf%3D1

Partz ,J.A., Lendrum, D.C., Holloway, T.C., & Foley, J.A. (2005). Impact of Regional Climate Change on human health. *Nature* . 438. 310-317.

Pittet, D.,Allegranzi, B., Storr, J., Bagheri, N.S., Dziekan, G., Leotsakos, A. & Donaldson, L. (2008). Infection control as a major World Health Organization priority for developing countries. *Journal of Hospital Infection*. 68. 285-292.

Practical Action. (2010). Promoting Adaptations to Climate Change in Bangladesh.

Pruss-Ustun, A., & Corvalan, C. (2007). How much disease burden can be prevented by environmental interventions? *Epidemiology*. 18. 167–178.

Reisen, W.K .(2010) Landscape Epidemiology of Vector-borne diseases. *Annual Review of Entomology* 55:461–483.

Rimi, N.A., Sultana, R., Islam, M.S., Uddin, M.,Sharker, M.A.Y.,Nahar, N.,…Gurley, E.S. (2012). Risk of infection from the physical environment in Bangladeshi hospitals: putting infection control into context. *International Conference on Emerging Infectious Diseases*. Retrieved from http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0089085

Sanderson, P.J., & Weissler, S. (1992). Recovery of coliforms from the hands of nurses and patients: activities leading to contamination. *Journal of Hospital Infection.* 21. 85-93.

Siddique, A.K., Baqui, A.H., Eusof, A. & Zaman, K. (1991). Floods in Bangladesh: pattern of illness and causes of death. *Journal of Diarrhoeal Research*. 9. 310–314.

Sobel, J., Gomes, T.A., Ramos, R.T., Hoekstra, M., Rodrigue, D., Rassi, V. & Griffin, P.M. (2004). Pathogen-Specific Risk Factors and Protective Factors for Acute Diarrheal Illness in Children Aged 12–59 Months in Sao Paulo, Brazil. Clinical Infectious Diseases. 38 . 1545-1551.

Teklemariam, S., Getaneh, T. & Bekele, F. (2000). Environmental Determinants of Diarrheal Morbidity in Under Five Children, Keffa-Sheka Zone, South West Ethiopia. *Ethiopian Medical Journal.* 38. 27-34.

Teshima, A., Yamada, M., Hayashi, T., Wagatsuma Y., & Terao, T. Climate impact on Seasonal patterns of Diarrheal Diseases in Tropical area . Retrieved from http://www.hyarc.nagoya-u.ac.jp/game/6thconf/html/abs_html/pdfs/T6AT09Aug04093113.pdf

Tumwine, J.K., Thompson, J., Katua-Katua, M, Mujwajuzi, M., Johnstone, N. & Porras, I. (2002). Diarrhoea and Effects of Different Water Sources, Sanitation and Hygiene Behaviour in East Africa. Tropical Medicine and International Health. 7. 750-756.

UNICEF. 2008. Bangladesh. Retrieved from http://www.unicef.org/bangladesh/cbg_%2818.10.08%29.pdf

United Nations Children's Fund (UNICEF) & World Health Organization (WHO).(2009).

"Diarrhoea : Why children are still dying and what can be done".

United Nations Children's Fund (UNICEF). (2010). Child Survival in Bangladesh. Retrieved from http://www.unicef.org/bangladesh/Child_Surviva_in_Bangladesh.pdf

Wang, L., Kanji, S. & Bandyopadhyay, S. (2009). The Health Impact of Extreme Weather Events in Sub-Saharan Africa. *Policy Research Working Paper*. 4979.

West, R.R. & Lowe, C.R. (1976).Mortality from Ischaemic Heart Disease: Inter-town Variation and its Association with Climate in England and Wales. International Journal of Epidemiology. 5. 195–201.

Weathe online. 2014. Bangladesh. Retrieved from: http://www.weatheronline.co.uk/reports/climate/Bangladesh.htm

Wijewardene, K., Fonseka, P. & Wijayasiri, W.A.(1992). Risk Factors Contributing to Acute Diarrhoeal Disease in Children below Five Years. *Ceylon Medical Journal*.37.116-119.

Woldemicael, G. (2001).Diarrheal Morbidity among Children in Eritrea: Environmental and Socio-economic Determinants. *Journal of Population, Health and Nutrition*.19. 83-90

.

World Health Organization. (1999).The Evolution of Diarrheal and Acute Respiratory Diseases Control at WHO. Retrieved from http://whqlibdoc.who.int/hq/1999/WHO_CHS_CAH_99.12.pdf

WHO. (2003). Cholera. *The Weekly Epidemiological record*. 79. 281–288.

World Health Organization. (2013). Diarrheal Disease. Retrieved from http://www.who.int/mediacentre/factsheets/fs330/en/

Wu, J., Green, A., Ahmed, K.M., Akita, Y., Alam, J.,… Emch, M. (2011). Increase in Diarrheal Disease Associated with Arsenic Mitigation in Bangladesh. *PLoS ONE.* Retrieved from http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0029593#pone.0029593-Bern1

Vesikari, T. & Torun, B. Health and Disease in developing countries. (1994). *Macmillan Education Ltd*. 136-146

Xu, Z., Huang, C., Turner, L.R., Su, H., Qiao Z., & Tong S. (2013). Is Diurnal Temperature Range A Risk Factor for Childhood Diarrhea? *PLoS ONE*. Retrieved from http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.00647

Xu Z., Liu, Y., Ma, Z., Toloo, G., Hu, W. & Tong, S. (2014). Assessment of the Temperature Effect on Childhood Diarrhea using Satellite Imaginary. *Scientific Reports.* Retrieved from http://www.nature.com/srep/2014/140623/srep05389/full/srep05389.html

Yassin, K. (2000).Morbidity and Risk Factors of Diarrheal Disease among Under Five Children in Rural Upper Egypt.Journal of Tropical Pediatrics. 46. 282-287.

Zaman ,S. (2004). Poverty and violence, frustration and inventiveness: hospital ward life in Bangladesh. *Social Science and Medicine.* 59. 2025–2036.

Zhao, Y.F., Guo, X.J., Zhang, Z.S., Ma, X.Q., Wang, R., … Tong, S. (2012). Epidemiology of functional diarrhea and comparison with diarrhea-predominant irritable bowel syndrome: A population-based survey in China. *PLoS ONE*. Retrieved from http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0043749&representation=PDF

CHAPTER 9: APPENDIX

9. Appendix

Source: UNICEF &WHO, 2009

Table-1. Total number of Annual Child Death Due to Diarrhea in 15 selected countries.

Rank	Country	Total Number of Annual Child Deaths Due to Diarrhea
1	India	386,600
2	Nigeria	151,700
3	Democratic Republic of Congo	89,900
4	Afghanistan	82,100
5	Ethiopia	73,700
6	Pakistan	53,300
7	**Bangladesh**	**50,800**
8	China	40,000
9	Uganda	29,300
10	Kenya	27,400
11	Niger	26,400
12	Burkina Faso	24,300

13	United Republic of Tanzania	23,900
14	Mali	20,900
15	Angola	19,700

Source: UNICEF &WHO, 2009