Climate Change: Impact on Disease transmission in South East Asia.

A Dissertation Report for

Post Graduate Diploma in Health and Hospital Management

By,

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Enrollment No. PG/10/009.

International Institute of Health Management Research

New Delhi – 110075

May, 2012.

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A dissertation submitted in partial fulfillment of the requirements

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Certificate from Dissertation Advisory Committee

This is to certify that Dr. Bhushan Chaudhari a participant of the Post- Graduate Diploma in Hospital and Health Management, has worked under our guidance and supervision. He is submitting this dissertation titled "Climate Change: Impact on Disease Transmission in South East Asia Region" in partial fulfillment of the requirements of the award of the Post- Graduate Diploma in Hospital and Health Management.

This dissertation has the requisite standard and to the best of our knowledge no part of it has been reproduced from any other dissertation, monograph, report or book.

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Date- 28/05/2012	Date-

Certificate of Approval

The following dissertation titled "**Climate Change: Impact on Disease Transmission in South East Asia**" is hereby approved as a certified study in management carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite for the award of **Post- Graduate Diploma in Health and Hospital Management** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

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06 February 2012

Dear Dr Chaudhari,

Subject: **Internship**

We are pleased to inform you that the Department of Sustainable Development & Healthy Environments (SDE), World Health Organization, Regional Office for South-East Asia, New Delhi, India, has accepted you as an intern.

The duration of your assignment is 13 February 2012 to 04 May 2012. During this assignment, Dr A.M. Zakir Hussain, Scientist (Environmental Health and Climate Change) would be your supervisor.

Please find attached the proposed objectives and outcomes as part of your programme of learning.

Should you have any queries relating to the technical content, we suggest you to please contact Dr A.M. Zakir Hussain, for clarification.

We should, however, point out that the proposed arrangement does not involve any cost to the Organization whatsoever, that is, no salary or living expenses or travel cost, etc., will be paid, nor would any employer-employee relationship be created. Any expenses incurred in connection with sickness or illness would be paid by you. You will, however, be covered during the approved period of your internship by an accident insurance policy. Kindly ensure that you have your own health insurance coverage.

A Certificate of Service will be issued at the end of assignment.

A copy of the signed Undertaking is attached. Kindly sign and return a copy of this letter.

Yours sincerely,

Anita Abhyankar
Regional Personnel Officer

Encl: as above

Abstract

It is very important to detect and measure the impact of Climate Change on Health and to provide the necessary evidence so as to support all the national and international policies related to its control and mitigation measures. This report analyzes the major principles through which climate change will affect health of the community through transmission of water borne and vector borne diseases, and looks for evidence of the same thorough various time series studies done. A systematic review of time series studies was done to assess the impact of climate change on disease transmission in South East Asia region. Results show significant impact of climate change on transmission of water borne and vector borne diseases in the region.

Acknowledgements

Any attempt at any level cannot be satisfactorily completed without the support and guidance of learned people. I owe a great debt to all the professionals at WHO-SEARO and IIHMR for sharing generously their knowledge and time, which inspired me to do my best during my dissertation.

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And final thank to my family and friends for their great moral support at all times during the project. I am also grateful to all those involved in the project, directly or indirectly.

Dr. Bhushan Chaudhari.

Table of Contents

Abbreviations

WHO	World Health Organization.
UN	United Nations.
SEARO	South East Asia Regional Office.
UNEP	United Nations Environment Programme.
WMO	World Meteorological Organization.
IPCC	Intergovernmental Panel on Climate Change.
EU	European Union.
JUSSCANZ	A group of countries namely Japan, United States, Switzerland, Canada, Australia, New Zealand and Norway.
IEC	Information, Education and Communication.
BCC	Behavior Change Communication.
CDC	Centre for Disease Control.
VBD	Vector Borne Disease.

Introduction to Organization.

World Health Organization.

World Health Organization (WHO) is an independent authority within United Nations (UN) for directing and coordinating Health. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends. This need for setting up a global health organization was felt by the diplomats when they met to form the United Nations in 1945. WHO' constitution came into force on 7th April 1948. This day we celebrate every year as World Health Day. World Health Assembly is the supreme decision making body for WHO.

Mission

The attainment by all people of the highest possible level of health.

WHO member states are grouped into six regions. Each region has its own regional office. These regions are

1. Regional office for Africa
2. Regional office for Americas
3. Regional office for South-East Asia
4. Regional office for Europe
5. Regional office for the Eastern Mediterranean
6. Regional office for the Western Pacific

WHO-SEARO

WHO's Regional Office for South East Asia caters to 11 countries in the region. These countries are Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand and Timor-Leste. WHO-SEARO office is strategically placed in New Delhi, India. This ensures that the regional activities are coordinated through the largest country and economy in the region to have enhanced decision making and to flourish the various initiatives.

WHO-SEARO mainly functions through its four departments,

1. Communicable Diseases.
2. Family Health and Research.
3. Health System Development.
4. Sustainable Development and Healthy Environments.

Sustainable Development and Healthy Environments

This department works to explore the links among health, environment and sustainable development. It works on the framework which extends from the epidemiological domain to the policy domain. It envisages and promotes the need for integrated action at all levels and especially on the need to focus on long term actions directed at mitigation of driving forces that generate the considerable environmental health threats.

Introduction

Svante Ahrrenius, a Swedish scientist, warned in 1898 that carbon dioxide emissions could lead to global warming. However, it was only after 1970's that scientists' growing understanding of Earth-environmental system brought this previously unnoticed field of science to wider attention. The United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) in 1988, to give policy makers and the general public a better understanding of what researchers had learned. The IPCC was given a mandate to assess the state of existing knowledge about the climate system and climate change; the environmental economic and social impacts of climate change; and possible response strategies. The IPCC released its First Assessment Report in 1990. It had a powerful effect on both policy makers and strongly influenced negotiations on the Climate Change Convention. In the view of growing scientific understanding, a series of intergovernmental conferences focusing on climate change were held in the late 1980s and early 1990s. In 1990, Second World Climate Conference featured negotiations and ministerial-level discussions among 137 states plus the European Community.

The final declaration did not specify any international targets for reducing emissions, but it did support a number of principles later included in the Climate Change Convention. These principles were climate change as a "common concern of humankind", "the importance of equity", "common but differentiated responsibilities" of countries at different levels of development, sustainable development and the precautionary principle – where there are threats of serious or irreversible damage, a lack of scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation. The United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, in June 1992—negotiators from 150 countries finalized the Convention in just 15 months.

The new Convention established a process for responding to climate changeover decades to come. A system was set up whereby Governments report information on their national greenhouse gas emissions and climate change strategies. In addition, close cooperation between developed and developing countries is being established to promote the transfer of funds and technology for combating Climate Change.

Both climate change and policies to minimize its effect have enormous environmental and economic implications. The costs of climate change will vary widely from country to country. Developed countries are responsible for over two thirds of past emissions and around 75 percent of current emissions. But they are well equipped to protect themselves from damage. Developing countries are having low per capita emissions, with need for economic development, and are also more vulnerable to climate – change impacts. All the countries are shaping their positions with focus on common interest in international talks. The key players are,

- The European Union.
- The JUSSCANZ countries. (non-EU developed countries)
- Countries with economies in transition.
- The Group of 77 and China.
- The Association of Small Island States.
- The Organization of Petroleum Exporting Countries.

It has been long time when we started studying global warming and climate change. Now sufficient evidence is available to show that Earth is warming over the years. And this change in temperature is also causing certain changes in the climatic conditions in different regions (Environmental Health Directorate, Western Australia). It is also being believed that climate change presents an urgent challenge to the well-being of all countries. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC) 4th assessment report, South East Asia will be the most affected region because of climate change as most of the economies here depend largely on agriculture and natural resources. It also makes it clear that while poor people worldwide will suffer most from the effects of Climate Change, no person on earth will escape from its consequences. Even if efforts to reduce greenhouse gas' emissions are successful, it is no longer possible to avoid some degree of global warming and climate change (Climate Change Impacts: South East Asia).

Sustainability of the health system depends on three key attributes,

Affordability for patients as well as service providers (Government)

Acceptability to both patients as well as health professionals.

Adaptability according to changing health needs due to changes in demography, technologies, diseases etc. (Harvey V).

It is now evident from different studies that the rate of warming and changing climate may not be slowed sufficiently to curtail the predicted effects. The trends observed in changing climate will have their effects on physical and biological components of the environment which in turn will impact the human population. The way, we adopt to situations and environments that may be quite different from those we have now, will determine the severity of the possible impacts on communities. Thus the efforts to mitigate the climate change and reduce emissions will determine the extent to which the climatic conditions will change, and thus the extent to which we will have to adopt ourselves for survival.

Fundamental requirements of health such as clean air, safe drinking water, sufficient food and secure shelter get affected due to climate change. Even if global warming may contribute to some localized benefits such as decrease in number of deaths due to cold in low temperature areas and increased food production in specific areas, the overall effect of climate change on health are likely to be overwhelmingly negative. Extreme high temperatures can be positively co-related with increasing number of deaths due to cardiovascular and respiratory diseases. Air pollution because of various sources contributes majorly in number of deaths per year. Globally, the number of reported natural disasters related to weather has increase more than three folds since 1960.Increasing sea levels and extreme weather conditions will add up to risk of range of health effects. Climatic changes are likely to increase the transmission season of important vector-borne diseases and the geographical range of these diseases will also be altered (Climate Change Factsheet 2010).

Vector-borne infectious diseases (VBD) are a significant cause of mortality and morbidity in the South East Asia countries. Important vectors of VBD’s are generally associated with water bodies. Major vector is mosquito, which lay eggs in water to produce larvae. Mosquitoes transmit many VBDs like malaria, lymphatic filariasis, and dengue. Schistosomiasis is transmitted by snail vectors. To minimize the vector breeding and human vector contact are the important components in efforts to reduce the spread of VBD. Climate change due to global warming can adversely affect human health. Global warming will also result in increased sea levels, which in turn will increase saline and brackish water bodies at coastal areas. These stagnant water bodies will serve as breeding fields for various vectors which transmit diseases, ultimately increasing risk for coastal population.

Climate change is expected to increase the severity of extreme weather conditions. These include storms, increased rainfall, flood risks and also drought in some areas. It will also increase average temperature of water bodies, thus providing favorable conditions for various bacteria and viruses which cause diseases (SDWF). Increased precipitation will increase the risk of flooding in coastal areas. These floodwaters are highly prone to be contaminated with various pathogens and chemicals. Developing countries are highly susceptible to the contamination due to lack of infrastructure, which allows the waste materials and sewage water to be mixed with the drinking water. Various diseases like cholera, diarrhoea etc. can outburst during the natural disasters.

Methodology

Statement of Problem

The climate change and global warming in future will be the biggest challenge for all countries whether they are developed or developing. Besides having environmental, economic and social effects, it will also severely affect health of human beings in direct or indirect way.

Hypothesis

The effects and implications of climate change on disease transmission for South East Asia not only pose environmental, socio-economic and public health challenges but also affords opportunities for sustainable development and green growth.

Method of data collection

The data has been collected from the following sources.

1. Library Books.
2. Periodicals and Journals.
3. Published IEC/BCC material.
4. Research and Reports.

Scope

The scope of the study aims at analyzing the effects of Climate Change on transmission of vector borne and water borne diseases among population residing in South East Asia. It also aims to understand the challenges and opportunities for the region.

This report has been restricted to the following,

1. Climate Change and its effects on transmission of water borne and vector borne diseases. (Diseases under consideration are Diarrhoea, Cholera, Rotavirus, Malaria and Dengue.)
2. Various Mitigation measures/Treaties.
3. Strategy to fight Climate Change.
4. Challenges.
5. Opportunities.

Climate Change and its Impact on Health.

It is very important to detect and measure the impact of Climate Change on Health and to provide the necessary evidence so as to support all the national and international policies related to its control and mitigation measures. However, the variation in climate can be natural as well as through human influences. Thus it is only one of the many determinants of health. There should be very careful analysis of the information so as to provide secure evidence of impacts due to climate change. For this the principles on which the data should be collected and analyzed must be clear. To attribute and relate the climate change and its influence on health, it should be separated from other factors affecting health.

This report analyzes the major principles through which climate change will affect health of the community through transmission of water borne and vector borne diseases, and looks for evidence of the same thorough various time series studies done. The principles under consideration are,

1. Effect of increasing water levels.
2. Effect of changing seasonal patterns.
3. Effect of extreme weather conditions.
4. Effect of increasing environmental temperature.
5. Effect of carbon cycle through ocean flux.
6. Effect of decreasing salinity of sea (Wilkinson et al.).

Chapter 1

Effect of Increasing Sea levels on Health.

One of the most acknowledged consequences of global climate change is sea level rise. It will have predictable impact on the environment and human health as the level will keep on rising for many years despite of various mitigation measures that the countries will take (USEPA). It has been observed that the sea level is rising worldwide through the last century. Sea level rise of approximately 12 to 22 centimeters is observed during last century.

James Titus has stated eight possible effects of sea level rise,

1. *Inundate wetlands and lowlands.*
2. *Erode shorelines.*
3. *Exacerbate coastal flooding.*
4. *Increase the salinity of estuaries and aquifers and otherwise impair water quality.*
5. *Alter tidal ranges in rivers and bays.*
6. *Change the locations where rivers deposit sediment.*
7. *Increase the heights of waves.*
8. *Decrease the amount of light reaching the bottoms.*

In view of these effects, sea level rise will require all coastal states and communities to plan for adaptation strategies. However, most of the human and social uncertainties also complicate the planning of adaptation strategies at national and international levels. The effects of sea level rise will occur for next few centuries, which make the planning for such a long period less practical (Craig et al.). Despite of this we can assume that certain basic human requirements and desires will remain same over the time period.

Sea level rise and coastal water supplies.

Due to rising sea levels, there is every possibility of salt water from sea entering into the fresh water reservoirs. This intrusion of salt water will have major ecological and public health effects. In public health perspective, the effects on domestic water supply are the most important consequences of sea level rise. These water supplies mostly depend on surface water like lakes and rivers or the underground aquifers accessed through wells. Both the sources are vulnerable to salt water intrusion (USEPA). The countries in South East Asia region are having large coastal areas. Island countries like Sri Lanka, Maldives and Timor-Leste will be have greater impact of sea level rise. The region have abundant sea coast with major cities situated near sea, thus making it most vulnerable to any rise in sea levels.

Sea level rise and changes in disease pattern.

Sea level rise will also contribute to the increased incidence and spread of various diseases like malaria, dengue. Along with the increasing temperatures, sea level rise will contribute to the much expected increase in incidence and spread of mosquito-borne diseases like malaria and dengue. These diseases are already posing problems for the developing economies of the region. Thus the increased incidence due to favorable environment may only add to the woes of the public health system. James Titus has noted that by deepening the shallow water bodies, a sea level rise could stagnate them. These warm, stagnant water bodies will be the perfect habitat for breeding of the mosquitoes. Though the region has shown reduction in malaria transmission and mortality, we must be able to sustain this positive change even in the view of rising challenges. The current upsurge in Dengue cases can be observed in the region with all countries having certain pattern in yearly occurrence of the disease. Though there is no evidence about this upsurge being correlated with climate change, we should have a careful approach so as to contain the spread of the disease. Policy maker should extract learning from various international experiences. Malaria has now returned in the countries like Peru, where it was almost eradicated 40 years ago. Also Centre for Disease Control (CDC) has already warned health officials in Texas about possibility of Dengue disease emergence there.

The sea itself also hosts disease bacteria and viruses, and increasing sea levels will also bring new and large communities under threat infection. Cholera disease, associated with the water bourn transmission, is also linked with the climate change and temperature (Lobitz et al.). The cholera bacterium, *Vibrio Cholerae*, has the sea stage. During this stage copepods act as host organisms. Cholera carrying copepods live in salt or brackish waters. Thus the increase in sea level will contaminate the local water reservoirs and thus assist in spread of the disease. Thus may be not coincidently, in this decade the spread of the disease has re-emerged in epidemic form in coastal areas of South East Asia, Central America and South America (Craig et al.). As a result of contamination, sea water is already becoming flourished with toxic algae. Various factors affect the marine algae, including temperature, agricultural deposits and other oceanic properties (Dobson et al.). Some of these algae produce toxic chemicals. When in high concentrations, these toxic materials can affect humans. The inland movement of sea water due to sea level rise can pose serious threat to public health. Even the melting ice can have serious health effects. It could potentially expose the human population to the long dormant strains of influenza, packed in the ice cover at remote places. Migratory birds and melting ice can spread these strains to various communities.

Chapter 2

Effect of changing seasonal pattern

Important factors behind high levels of climate vulnerability in South East Asia are related to high exposure and sensitivity to erratic climate conditions, high population densities and natural resource dependent communities, heavy disease burdens, as well as low adaptive capacity to adapt financially and institutionally. Livelihood conditions and activities differ considerably throughout the year rendering households more or less vulnerable to climate impacts. The change in seasonal pattern in the region will have considerable impact on human health as most of the nations are having developing economies and majority of the population is dependent on primary natural resources. Seasonal patterns are one major pathway for the subtle but potentially drastic effects of climate change on disease dynamics. Long-term climate change affects seasonal patterns through the lengthening of the transmission season and the crossing of environmental and demographic thresholds that underlie seasonal outbreaks. Thus, identifying the specific environmental factors underlying seasonal transmission is a critical step towards predicting and understanding how long-term environmental trends in mean climate and their variability will impact human health.

Chapter 3

Extreme weather conditions

Sea level rise surely affect the public health due to its serious consequences but its effects are slow and steady. Instead the increased destructive potential of the storms pose much higher risks to the population and public health system. According to James Titus, sea level rise provides "a higher base upon which storm surges could build, if sea level rises one meter, then the area which is flooded with 50 centimeters of water every 20 years today would then be flooded with 150 centimeter every 20 years. The surges will also penetrate the land farther inside the sea line.

This phenomenon of higher base for storm surges would be particularly important in the area where hurricanes are frequent (Craig et al.). In South East Asia region countries like India, Bangladesh and Myanmar face serious threats from hurricanes. To add to the situation, rising sea levels also erode coastal shores and submerges protective structures such as beaches and barrier islands etc. which otherwise would protect coastal infrastructures and human population. Loss of mangroves, wetlands, and marshes also makes it easier for storms to travel faster and deep within and cover larger land area. Sea level rise also impedes the drainage system and increases vulnerability of the coastal area to flooding (Craig et al.). Thus these hurricane prone areas should take particular interest in adaptation measures for reducing the public health impacts of storms.

Chapter 4

Increasing environmental temperatures

Although global warming may bring some localized benefits, such as fewer winter deaths in temperate climates and increased food production in certain areas, the overall health effects of a changing climate are likely to be overwhelmingly negative. Climate change affects the fundamental requirements for health – clean air, safe drinking water, sufficient food and secure shelter. Extreme high air temperatures contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people. High temperatures also raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease. Urban air pollution causes about 1.2 million deaths every year. Pollen and other aeroallergen levels are also higher in extreme heat. These can trigger asthma, which affects around 300 million people. On-going temperature increases are expected to increase this burden.

Chapter 5

Effect on Water borne diseases

WHO has produced several documents on the issue of climate change and health. It has been highlighted that infectious diseases like diarrhoea, cholera, severe and acute respiratory syndrome and vector borne diseases as well as respiratory diseases such as asthma, bronchitis and chronic obstructive pulmonary diseases are likely to be affected the most.

Diarrhoea

Diarrhoea morbidity is influenced by weather and climate variability (Victora et al. 1985, Salazar-Lindo et. al. 1997, Checkley et al. 2000). Temperature affects pathogen survival (Kovats & Tirado 2006), and water supply contamination due to heavy rainfall has led to diarrhoea outbreaks (Curriero et al. 2001, Auld et al. 2004). Drought events and water scarcity may reduce hygiene practices and necessitate the use of unprotected water sources (Moran et al. 1997). It is suggested that climate change may increase the burden of diarrhoeal disease due to temperature increases (McMichael et al. 2004).

Time-series studies examine the diarrhoea–weather relationship over a short timescale—for example, using weekly exposure and outcome data—and, in general, at a particular location.

A study done in Bangladesh by Lloyd et al. describes the co relation of diarrhoea with rainfall. Rainfall over a period of at least a year is a determinant of childhood diarrhoeal disease in low and middle income countries (Lloyd et. al 2007). It is also found that rainfall has a negative linear relationship with diarrhoea rates. Such a finding is plausible, as precipitation is a major determinant of stream flow and ground water recharge, with low levels potentially leading to water scarcity (Ahmad et al. 2001). This may in turn lead people to use less protected water sources, and reduce hygiene behaviour, resulting in increased diarrhoea incidence (Moran et al. 1997).

Studies of the association between rainfall and diarrhoea over the short term (weekly or monthly) have found both low and high rainfall increase diarrhoea incidence (Curriero et al. 2001, Singh et al. 2001). Such studies have linked outbreaks to extreme rainfall events. These outbreaks, however, are likely to be short-lived, and following initial contamination, continued rainfall is likely to dilute any pathogens and restore water quality (Singh et al. 2001). Thus, extreme rainfall events may have a relatively limited influence on long-term diarrhoea rates. In contrast, low rainfall, and the possible water scarcity, may lead to increased diarrhoea for the whole dry period duration. This may explain why a U-shaped relationship is seen in time series studies of short-term associations.

Climate change is likely to aggravate this situation, perhaps contributing to 20% of the future increases in water scarcity (Ahern 2006). As findings in this study suggest diarrhoea morbidity increases with water scarcity, the large number of people projected to have limited access to water in the future may be particularly vulnerable to diarrhoea. Further, recent research suggests repeated episodes of dehydrating diarrhoea may have chronic effects, including impairing growth and cognitive ability (Guerrant et al. 2002), and hypertension (Davey Smith et al. 2006, Lawlor et al. 2006). That is, the effects of diarrhoea morbidity may extend well beyond the acute event. More widespread water scarcity in the future may, through increased diarrhoea, have far reaching consequences, including an impact on the growing burden of chronic disease in low- and middle-income countries.

It was found that low rainfall may be associated with increased diarrhoea morbidity in children, most likely due to resulting water scarcity. Thus the impacts of low rainfall on diarrhoeal disease may be avoided by ensuring safe and reliable water and sanitation infrastructure. Findings also add support to efforts to improve global water and sanitation coverage, and may suggest one means of identifying the most vulnerable populations. Quantity of available water is strongly related to diarrhoea rates, and disease may be prevented by increasing access and/or improving microbial quality (Clasen et al. 2007). Additionally, the potential for climate change to increase water scarcity means this study adds some support to the need for mitigation and adaptation measures.

Another study by Hashizume et al. in Bangladesh shows relation between non-Cholera Diarrhoea, and rainfall and temperature. It shows that there was significant association of hospital visits due to non-cholera diarrhoea with high and low rainfall and with high temperature in Dhaka, Bangladesh. The effect of temperature on the incidence of non-cholera diarrhoea was higher for people with lower educational attainment, those living in the household with non-concrete roof and unsanitary toilet users. The effects of rainfall were not differential by any socio-economic status or hygiene and sanitation practices. This study found that the river level explained nearly all the associations between high rainfall and the incidence of diarrhoea, suggesting that factors associated with the river level are on the causal pathway between high rainfall and diarrhoea. Also a positive co relation is established among incidence of non-cholera diarrhoea and temperature rise. This finding is also biologically plausible through higher temperatures promoting the growth of bacteria, although some enteric viruses have been suggested to increase survival and transmission under lower temperatures. A new finding of this study is that the effect of temperature on non-cholera diarrhoea incidence is higher for people with lower educational attainment, those living in the household with non-concrete roof and unsanitary toilet users.

Cholera

Cholera is one of a number of infectious diseases that appears to be influenced by climatic changes (Colwell, 1996). Climate change influences the epidemiology of cholera, as cholera is a water borne disease, the changes of various bio-physico-chemical parameters of water e.g. temperature, salinity, pH, abundance of phytoplankton have an impact on distribution and survival of Vibrio Cholerae, the causative agent of cholera (Islam et al., 1994b).

A study done in Bangladesh by Climate Change Cell, Department of Environment in 2009 assesses the impact of climate change on transmission dynamics of Cholera. Significant association of maximum tidal height and cholera has been observed in this study. This relation was highly significant during flood. In 1998, maximum tidal height was considerably higher compared to average maximum tidal height in that area, as a result severe flood took place. A combination of these factors might be responsible for the severe outbreak of cholera in the same year. During flood, breakdown of sanitation system is very often reported in Bangladesh and heavy contamination of the surface water happens (Islam et al. 1994c), make people more vulnerable to contract cholera. This study also reveals association between local rainfall and cholera cases. Rainfall is a potential way of adding nutrients in the pond and other type of closed water bodies. Rainwater brings a lot of nutrients in water bodies from land. This influx of nutrients favours growth of algae, which serve as a reservoir of cholera. Study provides further evidence of the association of cholera with water temperature.

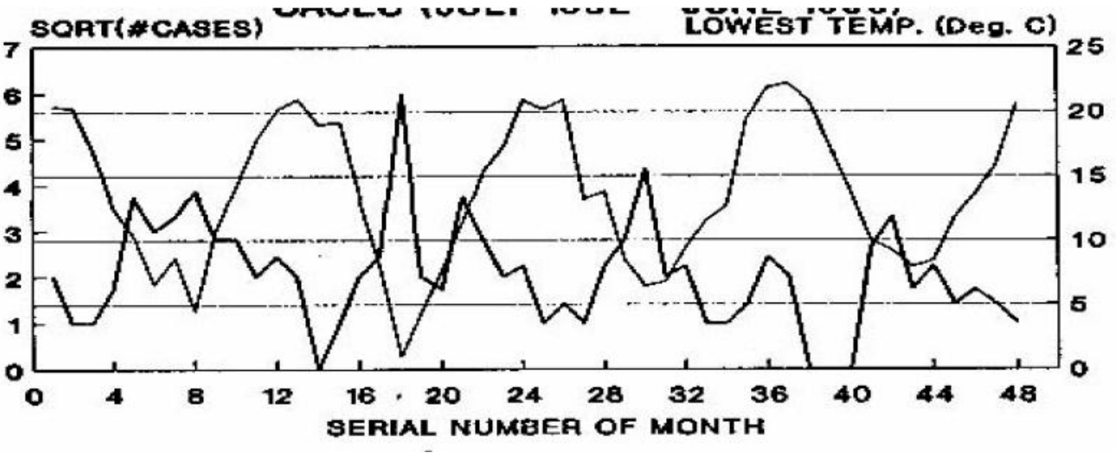
Another study done by Rajendran et al. at National Institute of Cholera and Enteric diseases shows evidence of the association of cholera with rainfall and relative humidity.

The relationship of cholera incidence with temperature and rainfall has been established in this study with statistical model approaches.

Rotavirus

Rotaviruses are the most common cause of diarrhoea in children worldwide. Since its discovery in 1973 rotavirus has been well documented as a causative agent of infantile gastroenteritis. There have been several studies on infantile gastroenteritis looking for both viral and bacterial enteropathogens.

A study done in Pune, India by Purohit et al. suggests strong influence of climatic changes on the incidence of the disease. Further study of weather parameters not only confirms that daily minimum temperature is the principal factor but also reveals that easterly wave, a characteristic feature of tropical weather, is useful in predicting the peak of hospital admissions and the geographical sequence of outbreaks of the disease in tropical India. Diarrhoea cases of all the age groups were monitored for rotavirus aetiology at the Naidu Infectious Diseases Hospital, Pune, India from July 1992 to June 1996. Rotavirus diarrhoea is endemic and has been observed throughout the year in tropical India.



Time series for lowest temperature and transformed rotavirus diarrhoea cases (July 1992-June 1996)

Figure 2

The prominent seasonality observed in rotavirus diarrhoea cases coincides with annual changes in the climate. Figure shows (i) the lowest minimum temperatures during the months, and (ii) the transformed number of rotavirus diarrhoea cases during the 48-month observation period. The comparison of these two clearly shows that the number of diarrhoea cases is inversely related to the temperature. It clearly shows that the number of diarrhoea cases is inversely related to the temperature. This study clearly suggests that rotavirus cases are more common in cooler months with seasonal peaks matching the lowest minimum temperature.

A common feature of tropical weather is the easterly wave, which normally forms the convergent flow of trade winds and moves from east to west. This study also captures the cyclical incidence of rotavirus diarrhoea. This suggests that the annual rotavirus epidemics may follow a regional sequence from east to west. Since rotavirus is the principal agent of winter diarrhoea, this temporal geographic sequence is likely to be associated with rotavirus.

Another study done in Dhaka, Bangladesh by Hashizume et al. attempts to explain the clear seasonality of rotavirus infections have been made by relating disease incidence to climate factors. They investigated the relationships between hospital visits for rotavirus diarrhoea and temperature, humidity and river level, in Dhaka, Bangladesh. Study findings provide evidence that factors associated with high temperature, low humidity and high river-level increase the incidence of rotavirus diarrhoea in Dhaka.

In Bangladesh, there appears to be a significant positive association between the number of hospital visits for rotavirus diarrhoea and temperature above a threshold after adjusting for potential confounding by humidity, river level and seasonal patterns. An inverse association between relative humidity and the number of rotavirus infections was also observed. Higher river level was associated with increased risk of rotavirus infections independently of these weather factors.

Chapter 6

Vector Borne Diseases

Malaria

Malaria still remains a public health problem in South East Asia region despite marked reduction of cases in last few years.

A study in Bhutan by Wangdi et al. shows temperature affects - the mosquito bionomics through the time required for development of the ookinete, the egg of the parasite, in the mid gut of the anopheline mosquito, which decreases as temperature increases from 21°C to 27°C. Increase in temperature also decreases the interval between mosquitoes' blood meals there by shortening the incubation periods of the plasmodium parasites in the mosquitoes and the number of times eggs are laid by the mosquitoes. A decrease in temperature would have the opposite effect.

When more climatic variables were added, rainfall was found as one of the significant predictors for only two districts. Rainfall provides aquatic medium for the growth and development of mosquitoes. But excessive rainfall might have a negative effect by washing off the breeding sites. In all, using climatic factors as predictors for malaria occurrence were different from one location to another; this pattern has been observed by several other studies.

A study done in southern India by Roy et al. shows temperature and rainfall have strong influence on the disease incidence and play important roles to shape the disease curve.

Another study by Laneri et al. in Northwest India analyses relationship between epidemic Malaria and monsoon rains. Malaria epidemics in regions with seasonal windows of transmission can vary greatly in size from year to year. The inter-annual patterns of epidemic malaria are investigated here for desert regions of northwest India, with extensive epidemiological records for Plasmodium falciparum malaria for the past two decades. Results show a significant effect of rainfall in the inter-annual variability of epidemic malaria that involves a threshold in the disease response. The model exhibits high prediction skill for yearly cases in the malaria transmission season following the monsoonal rains. Results indicate that the nonlinear dynamics of the disease itself play a role at the seasonal, but not the inter-annual, time scales. They illustrate the feasibility of forecasting malaria epidemics in desert and semi-arid regions of India based on climate variability. This approach should be applicable to malaria in other locations, to other infectious diseases, and to other nonlinear systems under forcing.

Dengue

Dengue fever is a mosquito-borne infection that causes potentially fatal complications like dengue haemorrhagic fever (DHF) and dengue shock syndrome. The global incidence of dengue has increased dramatically in recent decades. Climatic conditions directly affect the biology of the vector mosquitoes, *Aedes aegypti* and *Aedes albopictus*. High rainfall and temperatures can provide the conditions for oviposition, stimulation of egg-hatching, high vector development and a decrease in the reproductive period of the virus in the mosquito. Many studies have investigated the relationship between climate and dengue in various locations.

Dengue is described as 'endemic' in many countries in the SEA Region – which means that cases occur every year, although there is significant variation between countries and within each country. In 2003, eight SEA Region countries (Bangladesh, India, Indonesia, Maldives, Myanmar, Sri Lanka, Thailand and Timor-Leste) reported dengue cases. In 2004, Bhutan reported the country's first dengue outbreak followed by the first indigenous dengue case reported in Nepal in November 2006. At present, the Democratic People Republic of Korea is the only country in the South-East Asia Region that has no reports of indigenous dengue cases. Cases of dengue typically vary throughout the year and assume a regular pattern, normally in association with changes of temperature and rainfall.

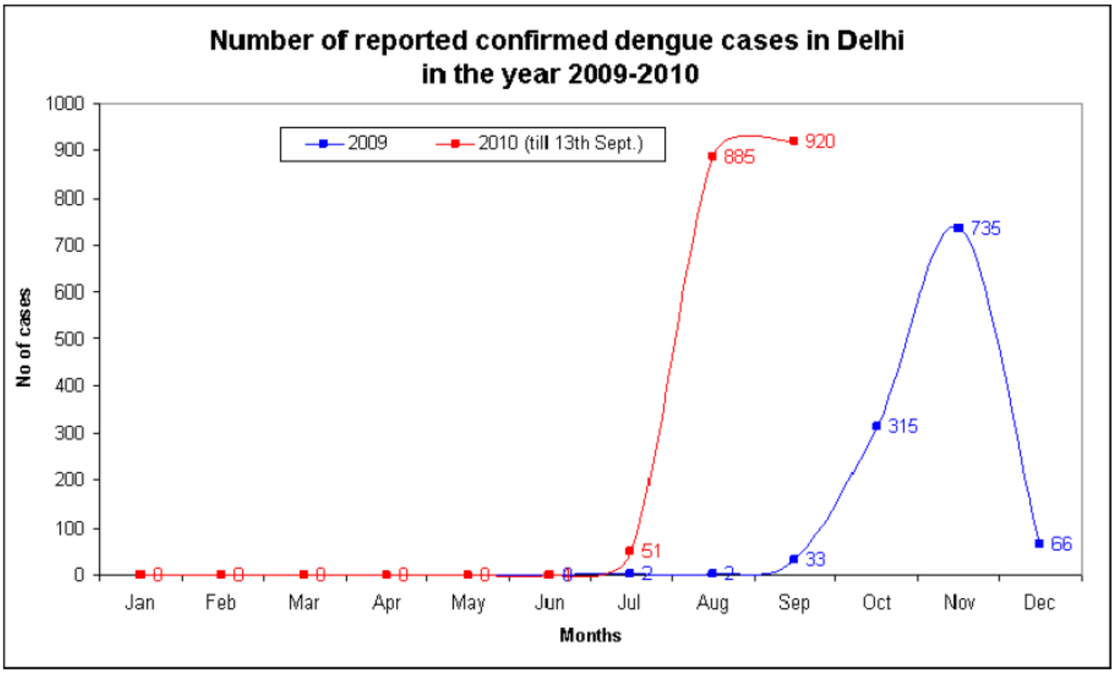
Hashizume et al. observed a significant association between hospital visits for dengue and high river levels with a short lag time (0–5 weeks) and with low river levels with a longer lag time (6–19 weeks) in Dhaka, Bangladesh. The results indicate that the number of dengue cases increased when a prolonged low river level preceded a high river level. Flooding in Dhaka is not caused by flash floods. Levels in water bodies scattered throughout the city gradually increase every monsoon season, and river levels can be good indicators of the level of water bodies in the community irrespective of the overflow of the major rivers. Thousands of pieces of garbage, including plastic containers, are scattered along water bodies. When water remains in discarded containers after the increased water levels recede, breeding conditions for the *Aedes* mosquitoes that are capable of spreading dengue may be created. *Aedes albopictus* is more likely than *Aedes aegypti* to breed and transmit dengue outside the home, and it is the principal vector of dengue transmission in Dhaka. Dhaka has unique topographical characteristics where the low-lying land and abundant bodies of water may be related to the observed association between river level and dengue incidence.

The estimates found in this study could be underestimated as data was collected from hospitals. Cases were clinically confirmed and not laboratory tested. Because systematic mosquito data for the study area were not available, the findings of this study do not represent a causal connection.

A study done in Thailand by Wongkoon et.al describes the relation between temporal changes and dengue incidence. There were total 634075 cases of dengue fever reported in north-eastern Thailand over the study period with major incidence peak in July 1987 of 17990 dengue fever cases. Study period is from January 1981 to April 2010.The dengue incidence varies widely from year to year. This study considers ARIMA model which co relates the factors like environmental temperature, vector dynamics for prediction of dengue transmission to derive early warnings through the data in previous months.

Study also co – relates factors like housing conditions, mosquito control measures, vegetation and irrigation system with transmission of dengue.

Figure 4: Number of reported confirmed cases of dengue in Delhi, India 2009-2010



Source – WHO factsheet.

A study in Thailand by Jeefoo et al. analyses spatio – temporal diffusion pattern in Chachoengsao province of Thailand. This paper presents a GIS approach to analyse the spatial and temporal dynamics of dengue epidemics. The major objective of this study was to examine spatial diffusion patterns and hotspot identification for reported dengue cases. Geospatial diffusion pattern of the 2007 dengue outbreak was investigated. Map of daily cases was generated for the 153 days of the outbreak. Epidemiological data from Chachoengsao province, Thailand (reported dengue cases for the years 1999–2007) was used for this study. Data was subsequently analysed for temporal patterns and correlation with climatic data (especially rainfall), spatial patterns and cluster analysis, and spatio-temporal patterns of hotspots during epidemics. The dengue temporal distribution in the whole province, with the highest incidence in the rainy season, presented a similar trend every year. The epidemiological trend of dengue follows the three seasons. The disease patterns indicated critical months from May to September that is during the rainy season.

The worst incidence was reported in July 2001 with more than 250 cases. Dengue outbreaks generally occurred during the first part of the rainy season, when humidity was higher than average. Rainfall (RF), temperature (TEMP), and relative humidity (RH) start to increase in May, consequently the dengue outbreaks reported during the months of June to August, having high rainfalls and humidity. Subsequently number of cases decreases in September when RF and RH were at their highest, but TEMP also showed a decrease. In conclusion, dengue cases were highly correlated with all climatic data, and observed better with one month before shift. The co relation with each indicator cannot be established independently through this study. Temporal analysis of climatic factors (rainfall, temperature, and humidity) showed that dengue generally occurs when average temperatures increase, when the humidity is higher than average, and when the rainfall season has already started. As shown, rainfall and relative humidity data of one month before (t−1) showed very high correlation with dengue incidence. These observations are coherent with the biology of vectors of viruses. It was shown in many regions that the minimum temperature is the most critical factor for the threshold of mosquito survival and developing rate in sustaining the population density.

Conclusions

It appears that climate change related sea level rise is occurring more rapidly and to greater potential than originally expected. As a result of extensive development and population densification along most of the coastal areas, climate change and sea level rise can create enormous public health and policy issues. Policy makers may have to choose from holding back sea or to retreat. Yet none of the institutions or government has been able to conclude on this point. In both the cases great political willpower as well as finance is required. Salt water intrusion may give rise outbreak of new diseases as well as those diseases which are on the verge of eradication. Community will also be under enhanced threat of chemical spillage through various industrial settings.

Transmission of vector borne and water borne diseases have potential impact of climate change. Changing environmental temperatures affects disease transmission dynamics in the region.

Opportunities

Adaptation measures for sea level rise.

The connection between sea level rise and disease can bring out an adaptation strategy for coastal states and local governments, Public Health Preparedness. These diseases will have a very huge impact on public health system as current systems are generally not capable of dealing with such major outbreaks. These diseases will present new medical challenges to many coastal communities. Thus training of health service providers in these communities to detect and treat these diseases and awareness of the population against possible health threats may be an appropriate adaptation strategy. These measures will allow public health professional to implement appropriate control measures in case of epidemics.

Adaptation measures for Extreme weather conditions.

For considering adaptation measures for extreme weather conditions, we can draw few learning from experience drawn through Hurricane Katrina and its flooding. It has suggested several adaptations for sea level rise that coastal states and local authorities should consider. At least, the contamination caused by Hurricane Katrina provides considerations for the city engineers and planning officials to demand that potentially toxic and biologically contaminative facilities like sewage treatment plants, hazardous waste disposal facilities, chemical manufacturers, power plants, oil and gas facilities, military facilities, etc. meet stringent design and maintenance requirements. It should be considered to seal potential contaminants to be stored in such a way that it cannot spill out in case of storms. Clean-up of existing and new contaminated sites along sea coast should be cleared on priority basis. Construction of new potentially contaminating facilities can be done above a certain height above sea level so as to avoid the possible impacts of storms. Local governments can adopt a policy strategy of closing down the facilities that are under threat due to increasing sea levels. Such facilities can be closed down gradually under normal course of the economic progress. Adaptation of such strategies can reduce the risk of contamination by limiting the number of such facilities in the possible reach of storm. Governments can also consider option of compulsory quarantine or immunisation measures in case of such devastating conditions.

Adaptation for controlling disease transmission

Availability of specific co relation between environmental factors like temperature, humidity and rainfall may provide us with future projections of the disease incidence. This will provide policy makers with important insights for predicting the future epidemics. Thus this will enhance the delivery system in delivering facilities for community with disease preparedness. Different models such as autoregressive integrated moving average (ARIMA), seasonal autoregressive integrated moving average (SARIMA) can be used for predicting the number of cases in certain geographical area.

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