

Effects of global climate change on disease epidemics and social instability around the world

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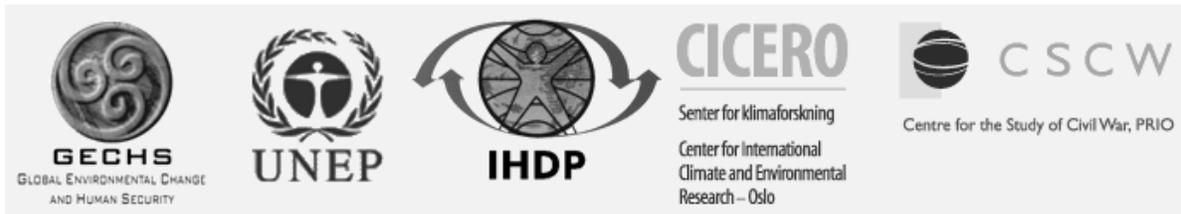
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Abstract

The impact of climate change on health status is different in developing versus industrialized countries. In developing countries, rising temperatures and humidity have facilitated the spread of many vector borne infectious diseases including malaria, dengue and encephalitis. The increasing prevalence of and mortality from these infectious diseases has had several negative consequences: decreasing economic productivity, increasing medical costs, and taxing already tenuous health care systems in poor countries. The rising frequency of extreme climatic events such as floods and droughts, render developing countries with increasingly less time to recover.

Industrialized countries also face challenges from increasing climate changes. Epidemiological studies conducted in industrialized countries have shown that climate-mediated air pollution has had a substantial impact among people with asthma, chronic bronchitis, allergies, and heart conditions. Populations in industrialized countries are also vulnerable to temperature-related mortality. Finally, as climate changes precipitate the spread of infectious diseases in the developing world, the ease of international travel facilitates further spread of these diseases to the developed world.

Importantly, when the pathogens of disease adapt to the new environments, the interaction between climate change and disease poses a serious threat to international health. As such, the international community must be cooperative and vigilant. Countries must be willing to communicate so that they may learn from each other's experiences. Also, resource-poor countries require support and assistance as they attempt to control the impact of climate change and disease epidemics.

1. Introduction

Climate change has important health-related consequences. These consequences including the emergence and re-emergence of infectious diseases, heat stress, and respiratory illnesses, demonstrates how global climate change interacts with the complex and rapidly changing social-political environment and consequently determine the security of individuals, communities and the society. Effects are observed in both chronic and acute disease, spanning both developing and industrialized countries.

Climate variability has affected many poor countries in Africa and Asia in the last few decades,

leading to a scarcity of food and clean drinking water (Department for International Development 2004). Systematic increases in mean temperature and precipitation, resulting in greater humidity, has facilitated the spread of many vector borne infectious diseases such as malaria, dengue and encephalitis. The increasing prevalence of and mortality due to communicable diseases, has not only affected the population's health, but also burdens society by lowering productivity, increasing medical costs, and taxing the tenuous health care systems characteristic of many developing countries. With the increasing frequency of climate-related "natural disasters" such as flood and drought, governments and institutions unprepared for coping with climate change must bare the threat to their health and economics. When these communicable diseases spread to other countries and adapt to the new environment, the impact resulting from the synergic effects between climate change and disease epidemics then poses a serious threat to international health. Many historical examples include the spread of cholera from Asia to Europe, Africa and the Americas since the 1800s and the spread of SARS from China to many Asian countries in 2003.

Industrialized countries also face the effects of increasingly frequent climatic events, resulting in a diverse array of conditions including temperature-related illness and the spread of tropical pathogens. According to reports from the Center for Disease Control and Prevention in the U.S., urban populations are most vulnerable to adverse heat-related health outcomes within heat-sensitive regions. Studies also report that the changing frequency of extreme climatic events has direct effects on human mortality and morbidity, such as respiratory disease and cardiovascular disease (Keatinge 2003; Haines and Patz 2004). In addition, epidemiologic studies already showed that people with some prevalent disease in industrialized countries, such as asthma, chronic bronchitis, allergy problem, and heart condition, suffered more from the impact of climate-mediated air pollution. Most importantly, because of global warming, the dengue viruses, *Ae. aegypti* and *Ae. albopictus*, have evolved to risk the relatively colder climate of both Asia and North America, causing a potential disaster in the form of an outbreak of dengue fever in these regions (Majumdar, Kalkstein et al. 1992).

This study reviewed several important health issues to demonstrate the impact of climate change on disease epidemics and their synergic impact on human health and social instability. We also addressed the observed and expected synergic impact of the relationship around the world.

2. Association between climate changes and the spread of vector-borne disease

Vector-born diseases, such as malaria, dengue fever and hantavirus pulmonary syndrome,

have threaten individual health and national security. In sub-Saharan Africa, at least 90% of deaths result from malaria (Greenwood and Mutabingwa 2002). In 2002, there were 4,146 cases and 284 deaths in the US from West Nile Virus; in 2003 the number of cases rose to 9,862 although the number of deaths decreased to 234. (O'Leary, Marfin et al. 2004; Hopkins, Jajosky et al. 2005). The West Nile Virus outbreaks were the largest outbreaks of mosquito-borne encephalitis recorded in the Western Hemisphere (Epstein, Chivian et al. 2003).

Climatic variations are thought to have a direct impact on the epidemiology of many vector-borne diseases. According to the World Health Organization, at least 30 diseases have emerged or resurgence since 1975 (WHO 1997). Factors which contribute to the emergence or resurgence of vector-borne disease are very complex. Two broad categories of factors include social transitions such as urbanization and globalization, and environmental changes such as climate change and ecological disruption (McMichael 2004; Sutherst 2004). Among these factors, an expectation of continuously increasing the intensity of climate change has drawn the attention of the researchers. Several studies using statistical models based on empirical weather data have concluded that climate change impacts epidemics of vector-borne disease, such as Ross Virus Fever in Australia (Woodruff, Guest et al. 2002) and malaria in Ethiopia (Abeku, de Vlas et al. 2002).

It is biologically justifiable to expect that climate changes could play crucial roles in determining factors which contribute to epidemics of vector-borne disease. Vector-borne diseases are characteristically transmitted through the effective contact between humans and the vectors. The occurrence of the disease depends on the triangle inter-relationship among hosts, pathogens and vectors (Sutherst 2004). Any influence among the triangle relationship will impact the epidemics of vector-borne infectious disease. For example, the increase density of vectors can enhance the opportunity of biting rate, leading to greater incidence of infection. Most importantly, almost all organisms, including vectors, pathogens and hosts survive and reproduce under a specific range of environmental conditions. Changes in temperature and humidity, could impact the breeding, maturation and survival of vectors, which consequently lead to changes in their geographic distribution (McMichael 2003). The optimal temperature is also associated with the incubation rate of the pathogen within vectors and lead to the differential risk of outbreaks by regions (McMichael, Campbell-Lendrum et al. 2003).

Malaria and dengue fever are endemic to more than 100 countries and represent the greatest

burden to human health among all vector-borne diseases. It is estimated that the annual number of deaths resulting from malaria exceeds 1 million; most of these deaths occur among African children aged 5 years or less. Currently, 40% of the total human population in the world is at risk for malaria and the proportion is projected to increase to 80% by 2080 (Sachs and Malaney 2002; Department for International Development 2004). Thus, malaria deserves further discussion to demonstrate the synergic effect of climate change and vector-borne infectious diseases on human health status.

2.1 Malaria

Malaria, a disease with great public health importance, is particularly sensitive to climate change. The disease burden from malaria is increasing but differentially distributed by region. For example, in certain areas in Africa, deaths from severe malarial anemia are increasing. Some of this increase may be the result of widespread HIV infection, which weakens the immune system, and also from the emergence of malarial strains that are resistant to the most common types of therapies (Greenwood and Mutabingwa 2002). Pregnant mothers, fetuses, and children are particularly vulnerable to malarial infection. In pregnancy, infections of malaria threaten both the survival of the mother and the fetus through the infected placenta, leading to abortion, stillbirth or low-birth weight birth (Miller, Baruch et al. 2002). In children, around 20% mortality from cerebral malaria and a few residual effects from recovery, such as neurological defects in 10% of survival children, has substantially deepened children's vulnerability in future behavior and career development (Holding and Snow 2001).

The effect of malaria epidemics has also been observed in a national scale. A high infant mortality rate has been linked with a poor fertility control program in many countries, which lead to considerable child-rearing activities in women and lower investment in younger generation. Reduced productivity of women and generations of poorly educated children, e.g. knowledge deficits regarding health behavior, lead countries into a vicious cycle of poor development. A strong correlation between malaria epidemics and national poverty has been proven from historical data (Sachs and Malaney 2002).

Temperature is a crucial determinant in the proliferation rate of *Anopheles* mosquitoes and also the maturation rate of the parasites within the mosquitoes. For example, the lowest temperature for the development of *P. falciparum* mosquitoes is 18°C. As temperature declines, so does the development of malaria parasites and the biting activities of mosquitoes. In addition, the incubation

time for *P. falciparum* is 26 days at 20°C but when the temperature is increased to 25°C, the incubation period is shorted to 13 days (Bunyavanich, Landrigan et al. 2003). These biological characteristics explain why effective malaria transmission can occur only in areas with a temperature higher than 20°C (Lindsay and Martens 1998) and indicate the potential role that increasing temperature can play in the transmission of vector-borne disease.

Although biological plausibility supports the hypothesis that increases in temperature result in greater malaria transmission, this idea is still a matter of debate. Some studies have supported that regional warming has led to resurgence in malaria although a few studies contend that the effect of highland malaria resurgence is independent from climate change because no statistically significant trend response was observed (Hay, Cox et al. 2002). Uncertainty about the exact impact of climate change on malaria epidemics demonstrates the difficulty in elucidating the direct cause of infectious disease epidemics. However, the relationship between malaria and climate can not be ignored given the following: 1) the biological plausibility, 2) many examples of malaria epidemics following extreme climate events, and 3) many modeling studies reporting a positive relationship between temperature and malaria epidemics. Given the substantial impact of malaria at both the individual and societal level, it is important to closely cooperate meteorologists, epidemiologists, microbiologists and community people in epidemic areas to implement more well-designed studies. Such studies are necessary to gather convincing evidence about the role of climate change in the resurgence of malaria.

3. Climate changes lead to increased rates of disease outside infectious disease

Increases in global temperature have had affected people differentially by regions and within population. Warmer temperatures have led to increased atmospheric pollution and pollen production, which consequently have impacted on the increased risk of respiratory disease. Children are especially vulnerable to decreases in air quality because of their narrowed airway and because they are less vigilant in protecting themselves against air pollution (Bunyavanich, Landrigan et al. 2003).

Extreme temperature events such as heat-waves, have led to lower worker productivity and thousands of death in many countries, particularly developing nations. Elderly people are more vulnerable to periods of extreme temperature, especially when they suffer from other comorbidities (Keatinge 2003). While air-conditioning is the most effective short-term method to avoid the heat stress, in the long-term its only indirectly increases the burden of global warming by more energy

consumption.

3.1 respiratory diseases

The combination of climate change, such as warming temperature, and local air pollution is a risk factor leading to an increased incidence of respiratory disease, such as chronic obstructive pulmonary disease (COPD) (Gross 2002), asthma and bronchitis. High temperatures, for example, may trigger forest fires, which results in the release of soot particles and contributes to an increase of respiratory disease. In Malaysia and Brazil, an increase in the number and extent of forest fires were associated with the increased outpatients' visits for respiratory disease (Haines and Patz 2004). A similar relationship between forest fires and health care needs was also demonstrated in the US. In 1998, there were extensive wildfires in Florida. As compared to the preceding year, emergency department visits increased 91% for asthma, 132% for bronchitis with acute exacerbation and 37% for chest pain. (CDC_US 1999). While not conclusive, these examples indicate climate change could decrease health status.

Climate changes also result in increased periods and amounts of pollen production, another source of respiratory disease. The association between warmer weather and increased pollen production has been supported from biological experiments and observational data. An experimental study found, when the concentration of carbon dioxide (CO₂) was doubled from 300 ppm to 600 ppm, the amount of *ambrosia artemisiifolia* (ragweed) pollen, a kind of highly allergenic pollen, showed an almost 4 folds increase in amount (Ziska and Caulfield 2000). In Denmark, a study found a significant positive correlation between the annual-total amount of birch pollen and the mean temperature in two cities located 200 km apart from each other. The increase temperature also fostered the start of pollen season around two weeks earlier than before (Rasmussen 2002). Exposure and sensitization to pollen can cause many allergic diseases, including allergenic rhinitis, allergenic asthma and hay fever (Bunyavanich, Landrigan et al. 2003). Through the increase of pollen production, climate change has played a role to increase people's vulnerability in allergic disease.

3.2 Extreme temperature-related illnesses

Heat stress can cause a variety of health conditions including syncope, cramps, exhaustion, and stroke. Heat stress causes dehydration through the loss of salt and water in sweat, which in turn leads to higher blood concentrations, increasing the risk of cerebral and coronary thrombosis, potentially precipitating stroke (Kovats and Haines 2005). Besides biological plausibility,

epidemiological studies have proposed a V-like relationship between temperature and mortality (Huynen, Martens et al. 2001; Curriero, Heiner et al. 2002). Curriero et al. performed time-series analysis to examine the temperature-mortality relationship in 11 large cities of the eastern United States. This study concluded that current and recent days' temperature were important predictors of mortality among all investigated factors in the study. In addition, heat stress had a greater impact on people living in colder areas than people living in warmer areas, and vice versa. Although global warming is a universal phenomenon, these findings supported that illnesses related to extreme temperatures could be differential among people in different regions.

The increased mortality from heat- and cold-related illness during extreme climate events has been reported in many industrialized countries. In France, an estimated 14,800 deaths was attributed to heat waves occurring during the period of August 1 to Aug 20, in 2003. An excess mortality by 142% was observed in Paris (Vandentorren, Suzan et al. 2004). A significant increase of mortality in all heat wave events and cold spells was also observed in Netherlands, especially among elderly people. An average of total excess mortality was as high as 39.8 deaths per day (12.1 %) and 46.6 deaths per day (12.8%) during the heat weave events and cold spells, respectively (Huynen, Martens et al. 2001). These examples illustrated extreme weather events, such as heat waves and cold spells, could also threaten the human security in developed regions, such as Europe.

4. Differential synergic impact between climate change and disease epidemics by regions

Climate changes has had the greatest impact on populations in developing countries, which are already most vulnerable to health problems. The World Health Organization (WHO) estimated that the modest climate changes between the middle of 1970s and 2000 have caused an annual loss of over 150,000 lives and 5,517,000 disability-adjusted life years (DALYs). However, the loss of DALYs per millions differs substantially by region, with 3071.5 DALYs in Africa and 111.4 West Pacific (Campbell-Lendrum, Pruss-Ustun et al. 2003).

Several reasons could explain why populations in developing countries are disproportionately affected by climatic changes as compared to populations in developed countries. First, populations in developing countries already face shortages of basic resources such as clean water and sufficient food; climate changes can exacerbate these shortages. Second, these populations cannot afford the resources, such as environmental controls of malaria, to prevent the spread of infectious diseases. As climate change favors the spread of vectors, these populations have little recourse. Populations in developed countries, on the other hand, have at least the financial resources to implement vector

control programs as needed. Finally, populations in developing nations are vulnerable to climatic changes because their governments do not have the resources or forethought to consider the impact of climate change on disease epidemics. With climatic changes projected to become more frequent in the future, we must protect against the growing gap of health disparities between developed and developing nations.

In Africa, many historical events have demonstrated that climatic change worsens disease epidemics, resulting in diminished human and national security. It has been observed that the distribution of many vector-borne diseases, such as malaria and yellow fever, are greatly restricted to regions in “climate envelopes”, where local climate supports disease transmission. However, as a result of climate change, the intensity of disease transmission has varied in the region in the past few decades (Thomson, Connor et al. 2004) Natural disasters resulting from climate change, such as floods and droughts, have expanded the range of some infectious diseases, resulting in greater social instability. For example, in the 1970s and 1980s in West Africa, drought and famine resulted in increased infectious disease. During epidemics of many infectious diseases, drought and famine led to increased social instability and population displacement (Prothero, Thomson et al. 1994).

In Asia and the West-Pacific, epidemics of vector-borne disease and respiratory disease have arisen, in part, as the result of climate change. In Southeast Asia, a high frequency of forest fires has been shown to increase risk of respiratory disease (Department for International Development 2004). Malaria is currently most endemic in South Asia and Southeast Asia (Department for International Development 2004). But the epidemics of malaria could change in an interaction with climate change, urbanization, and deforestation. In this global village era, rapid air travel poses the threat of introducing foreign pathogens into isolated regions. For example, the SARS virus was transmitted from China to Toronto via infected airplane passengers in 2003.

The different impact of climate change on disease burden can also be observed by contrasting populations in North American with those in Central and South America. In the United States, studies modeling the relationship between weather and mortality have concluded that populations in northeastern and Midwestern U.S. cities are in more vulnerable to experience heat-related illness or death than the rest of the U.S. (McGeekin and Mirabelli 2001). In Latin America, climate changes placed populations at increased risk of malaria, dengue and water-borne disease.

In Europe, climate changes may potentially expand the reach of vector-borne disease such as

malaria, dengue fever, and West Nile Virus. It is important to note that some resource poor states in Eastern Europe have large transient populations of refugees and weak health service infrastructures. These factors reflect their inability to cope with climatic extremes and disease epidemics (Githeko, Lindsay et al. 2000). Continued global warming is expected to contribute to increased rates of heat-related illness in Europe. Modeling studies project that the annual heat-related death rate in Lisbon, which was 5.4 - 6 / per 100,000 for 1980-1998, would increase to 5.8~15.1 /per 100,000 for the 2020s and 7.3~35.6 /per 100,000 for 2050s (Dessai, Prothero et al. 2003).

It is important to note that the impact on health from extreme weather events is not universal among populations in the same region. The inabilities of poor people to adapt to climate changes have led them limited access to clean water, food supply, preventive measures, and health care in the early onset of the syndrome. An epidemiological study by Schwartz found that the impact of climatic change on health status was greatest among people with lower socioeconomic status and poor health status. This study found that the increased risk of dying among COPD patients on cold days (odds ratio = 1.19, 95% C.I. = 1.07, 1.33). In addition, this study observed nonwhite people was with increased risk of dying, regardless of in hot days (OR= 1.22, 95% C.I. = 1.09, 1.73) or cold days (OR= 1.25, 95% C.I. = 1.02, 1.26) (Schwartz 2005). Thus, efforts to avoid the increase of health disparity resulting from climate change should also be made within a society to assure human security and social stability.

5. Conclusion

The interaction between climate change and disease epidemics has had an impact on both developing and industrialized countries. However, this impact is disproportionate. As developing countries continue to struggle with climate variability, the increased frequency of this variability leaves them with less and less time to recover. Their vulnerability increases when the effects of climate change are compounded with the effects of endemic communicable diseases, such as malaria and HIV/AIDS. It is necessary for developed nations to assist developing nations to cope with the health problems resulting from these climatic changes. Interaction between global warming and ease of transportation between continents has facilitated the spread of vector borne diseases. No country is safe from invasion by pathogens unless an international effort is made to continually take action, share experiences and assist poor countries in controlling the impact resulting from climate changes and disease epidemics.

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