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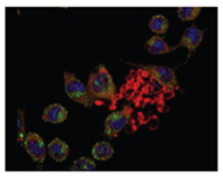

Special Focus Section: Climate Change

ISSN: 2150-5594 (Print) 2150-5608 (Online) Journal homepage: http://www.tandfonline.com/loi/kvir20

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To cite this article: Ulisses EC Confalonieri, Júlia Alves Menezes & Carina Margonari de Souza (2015) Climate change and adaptation of the health sector: The case of infectious diseases, Virulence, 6:6, 554-557, DOI: 10.1080/21505594.2015.1023985

To link to this article: http://dx.doi.org/10.1080/21505594.2015.1023985

Published online: 15 Jul 2015.

Virulence 6:6, 554–557; August/September 2015; © 2015 Taylor & Francis Group, LLC

Climate change and adaptation of the health sector: The case of infectious diseases

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Keywords: Adaptation, Climate Change, Health, Infectious Diseases, Outbreaks, Surveillance, Vulnerability

Infectious diseases form a group of health problems highly susceptible to the influences of climate. Adaptation to protect human population health from the changes in infectious disease epidemiology expected to occur as a consequence of climate change involve actions in the health systems as well as in other non-health sectors. In the health sector strategies such as enhanced and targeted epidemiological and entomological surveillance and the development of epidemic early warning systems informed by climate scenarios are needed. Measures in other sectors such as meteorology, civil defense and environmental sanitation will also contribute to a reduction in the risk of infection under climate change.

Introduction

The last report of the Intergovernmental Panel on Climate Change (IPCC) stated that globally averaged combined land and ocean surface temperature data showed a warming of 0.85°C over the period 1880 to 2012. It also pointed that changes in many extreme weather and climate events have been observed since about 1950.[1] These phenomena are considered as indications of anthropogenic changes in the global climatic system.

One category of healthcare affected by the process of global climate change is that of the infectious and parasitic diseases.[2-3] Different groups of infections, according to the mode of their transmission, will be affected: vector borne; water-borne, airborne and zoonosis. The mechanisms involved in the influence of climate on infections range from the effects of temperature on the lifecycle of both pathogens and vectors,[4-5] to increases in the concentration of pathogens in water due to alterations in the precipitation in urban settings or in natural ecosystems.[6-7] Indirect effects are associated with social/ demographic phenomena such as human migration of environmental refugees (eg. after long droughts in developing countries).

Adaptation to the impacts of global climate change is a concept originally developed by the Intergovernmental Panel on Climate Change. It is defined as "...a process by which strategies and measures to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, implemented and monitored."[8]

The endemic infectious diseases form a group of health outcomes which have been frequently investigated in their relations to the impacts of climatic change.[5,9,10] In this article we review the issue of how health care systems and the infectious disease control programs should change their practices in order to cope with the increasing challenges posed by global climate change.

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Submitted: 09/22/2014; Revised: 01/14/2015; Accepted: 02/22/2015
http://dx.doi.org/10.1080/21505594.2015.1023985

Climate Change and Infectious Diseases

Among the large group of human pathogens, those that are most susceptible to the influences of climate variability are those that have part of their life cycle spent in the extra-host environment . This may be in the physical environment (eg. water), or in other organisms such as insects vectors or vertebrate animal hosts. Those infections that are transmitted through direct contact or that depend on airborne transmission have their microbial causal agents more protected from the effects of climatic factors (temperature; humidity etc) in the external environment.

Figure 1 depicts the most common ways through which climate can influence infectious diseases in human populations, either directly or indirectly.

Changes in baseline climatic conditions, such as average daily temperatures or seasonal precipitation, can affect the developmental biology of pathogens and vectors.[5] Increased temperatures often shorten the duration of the life cycle of parasites such as the malarial *Plasmodium*.[9,11] On the other hand, specific amounts of precipitation can facilitate the formation of breeding sites for insect vectors, such as mosquitoes. The Ebola virus infection, which recently has had a dramatic increase in incidence in Africa, had in the past its outbreaks associated to dry conditions at the end of the rainy season in some African countries.[12]

Modifications in the baseline conditions of the physical and biological environment, as a consequence of climate change, can alter the so called "ecological niches" of vectors of diseases.[13] This creates ideal conditions for the build up of populations of these arthropods, thereby resulting in the expansion of the geographical area of distribution of a given vector species, with the potential increase in the incidence and distribution of the infections they transmit.

Besides the changes in baseline climatic conditions other climatic phenomena such as the extreme hydro-meteorological events (storms; floods; droughts) can alter the dynamics of vector

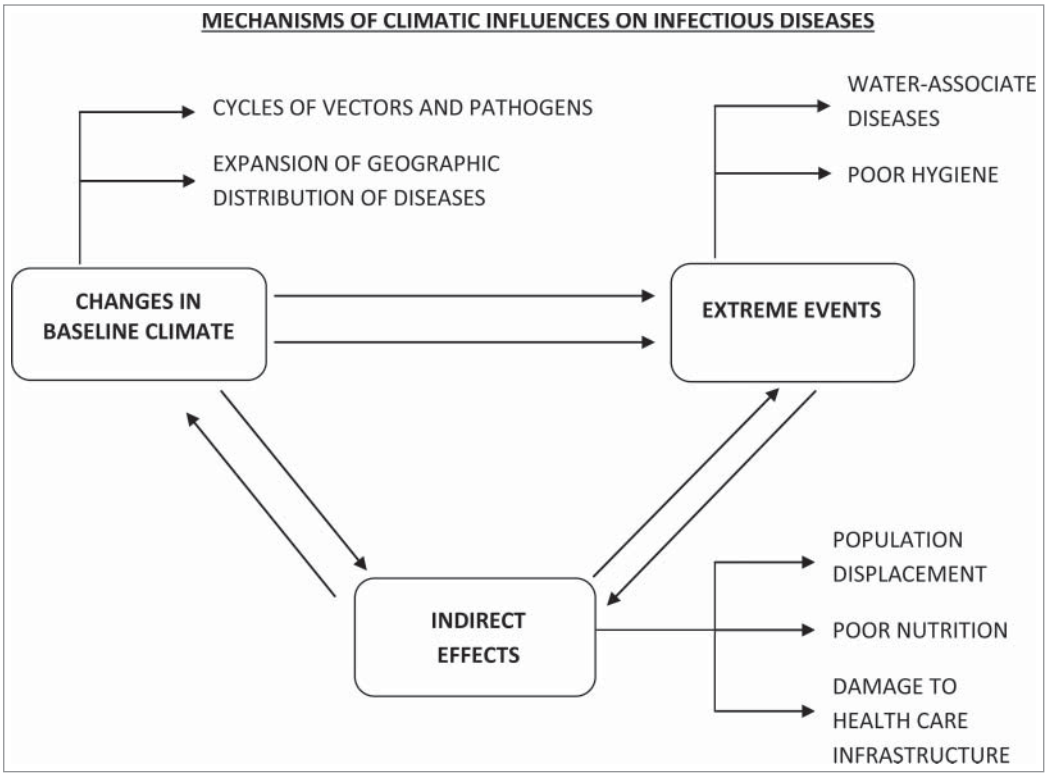

Figure 1. Mechanisms of Climatic Influences on Infectious Diseases.

and pathogen populations and, as consequence, of infectious diseases. Water-related infections, such as leptospirosis, occur frequently in epidemic form after floods, especially in urban areas of developing countries, where poor sanitation is common.[6-7]

Other extreme events such as droughts, which may have severe and lasting effects in poverty-stricken areas, often facilitate an increase in the incidence of infections due to poor hygiene standards resulting from water scarcity. This is often the mechanism involved in outbreaks of childhood diarrhea and skin infections, often seen in less developed areas.

Climate change can also indirectly affect human health. For example, population displacement and migration of people affected by weather disasters, especially by droughts, can cause changes in disease landscape. Chronically infected people can spatially redistribute some infections from the endemic areas to other areas previously non infected, such has been observed with visceral Leishmaniasis in the Neotropics.[14]

Another contributing factor for increased disease incidence is poor nutrition, very often caused by economic conditions but also aggravated by lost crops due to prolonged droughts in areas of subsistence farming in developing countries.[15]

Indirectly, climate change can also affect the incidence of infectious diseases through damage to health care infrastructure and the disrupting disease control programs. These disruptions may eventually be caused by extreme weather (hurricanes; floods) and may delay, or even prevent, the timely treatment of acute infections, such as malaria, dengue fever, diarrhea and others, with important epidemiological consequences.

Climate Change and Adaptation in the Health Sector

The steady process of change in the frequency and variability of climatic events require the development of strategies to reduce the impacts of climate change upon human population health. For this, the management of risks to health through primary prevention is essential.

Although most countries have well established public policies to promote human health many are not prepared to deal with the range of problems associated to the consequences of climate change.[16] Many countries still need to improve their capacities to formulate and implement adaptive strategies for health protection. This would imply the reduction in many determinants of vulnerability to the impacts of climate, especially in low and middle income countries. Among these are the reduction in poverty and the improvement in the quality of education, the effective control of climate-sensitive diseases and improved access to health care and sanitation services.

Since the impacts of climate change will be felt differently across the planet, the adaptation measures will depend on local or regional characteristics such as the availability of resources, the profiles of vulnerability, the patterns of exposure to the hazards, on the capacity of decision makers to use the information available and the public perception of the problem.[17,18]

A general approach to adaptation that can have health benefits is the enhancement of social capital. This involves the organization of a network of resources and the strengthening of social linkages that can help to reduce vulnerability and increase community resilience. Assessments have pointed to the advantages of social capital for adaptation but the barriers for its development have not been fully assessed.[19,20] Research has pointed that belonging to a social network can have a protective effect against heat-related illness[21] and population groups who are excluded from access to resources and decision making (low level of social capital) in the adaptation process are regarded as more vulnerable.[22] However, some authors have argued that strong binding networks do not necessarily reduce vulnerability to the effects of climate change.[23]

One general strategy for adaptation in the health sector is epidemiological surveillance which can provide an early detection of changes in incidence, mortality and geographic range of health

outcomes associated with climatic change. This would be achieved through regular reporting of specific health outcomes and routine statistical analysis of the data.

Among current barriers to the implementation of appropriate adaptation policies and strategies are the situation of social inequality and the wrong perception by decision makers that health risks caused by climate change are a problem for the future and should have low priority in health policy.[20] Other barriers include the complexities of disease transmission and the inherent uncertainties with projections of future health impacts under different scenarios.[18,20]

Adaptation for Infectious Diseases

In the specific case of infectious diseases, we should ask the following question: What does it mean to adapt to the impacts of climate change? In practical terms, it means to prepare individuals and societies for the expected changes in the behavior, distribution and incidence of these diseases and to reduce their vulnerability to infection.

For that, the first important acknowledgment is that infectious diseases result from a range of different determinants: individual (behavior); social (economics; health care) and environmental, including the climatic conditions. Therefore, adaptation measures should include actions in the health sector and also in other sectors such as meteorology (weather forecast and early warning systems), sanitation and civil defense. Strategies undertaken in these non-health sectors would both reduce the environmental risks of infection and improve the efficacy of public services for the protection of the population.

A adaptation strategy within the health sector should be focused both on primary prevention (reduction of exposure to infection) and secondary prevention (health care).

Important health adaptation actions include:

(a) Enhancement of epidemiological surveillance actions, targeted to specific territories, due to the expected expansion of the distribution of endemic infections is the emergence of diseases in new areas. This would be guided by information from climatic scenarios downscaled to specific regions and their implications in relation to disease cycles.

(b) Development of early warning systems for epidemics, especially after extreme hydro-meteorological events, such as storms and floods. Outbreaks of water-associated, waterborne and mosquito born infections are commonly reported after these events.[6,7,24]

(c) Within the field of health systems, strategies to facilitate access to health care services would assist in early detection and treatment of infections and, thereby, potentially outbreaks. This should preferably be directed to the more vulnerable populations and territories.

(d) Important adaptation actions are also those focused on specific disease and vector control programs, including entomological surveillance. The goal of these actions would be a reduction of the risk of infection, through the reduction of the populations of pathogens, vectors and animal reservoirs of infection.

The strategies mentioned above are based on the assumption that the epidemiological changes resulting from climatic change are – and will be- an exacerbation of already known infectious diseases, as well as of other health outcomes.[2] The intensification of disease transmission and/or their expansion to new areas due climate shifts are expected, but not the emergence of unknown diseases, since disease emergence is usually linked to a host of factors other than climatic events.

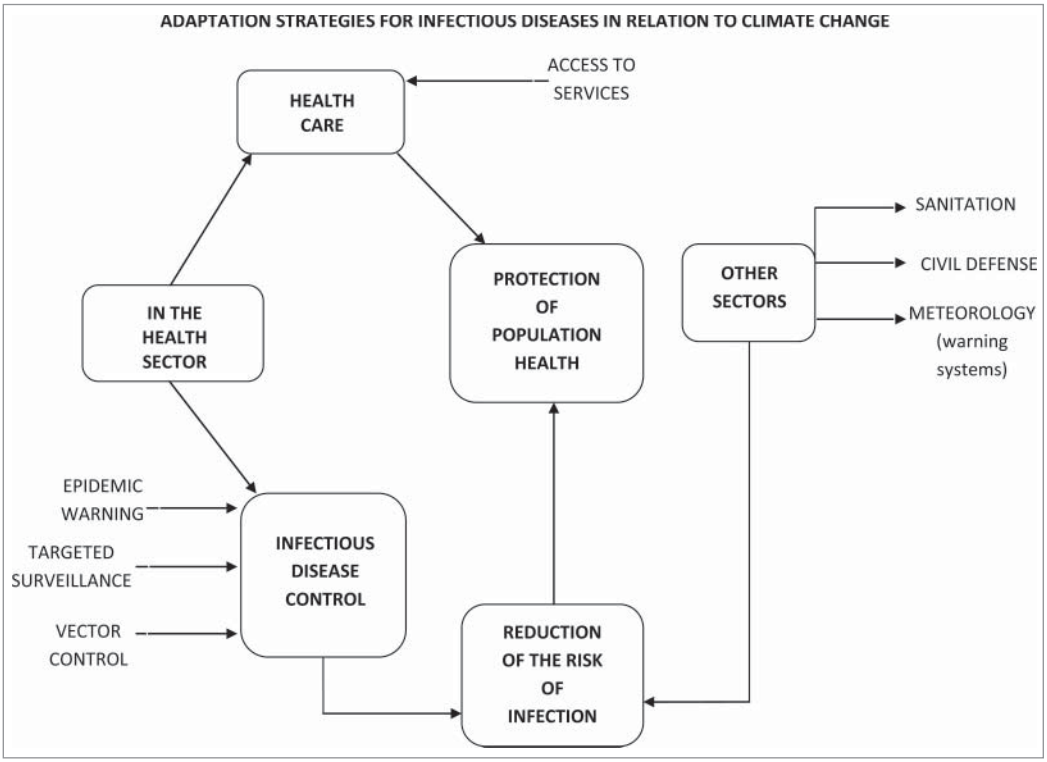

Figure 2. Adaptation strategies for Infectious Diseases in relation to Climate Change.

In relation to adaptation strategies in non-health sectors that will have an impact in the reduction of infectious disease incidence, those linked to improved sanitation (clean water supplies; garbage collection; sewage treatment and disposal) are important measures for the reduction of environmental contamination by microbial pathogens. On the other hand, the sanitation infrastructure under climatic change run the risk of damage due extreme weather (eg storms followed by floods) and also due to impacts in coastal cities caused by sea level rise.

Meteorological services are highly relevant for the development of early warning systems to protect the population from the impacts of extreme weather events and their health impacts. These systems would guide interventions by civil defense agents help to increase the resilience of communities affected by disasters and reduce their exposure to infection.

The diagram in **Figure 2** synthesizes the adaptive strategies discussed above.

Conclusions

Although adaptation to protect human population health from the impacts of climate change should be developed primarily within the health system, strategies in other sectors are also critical. These strategies shall contribute both to primary prevention, through the reduction of microbial contamination of the environment, and also to improve public assistance. Many of the adaptation measures focused on climate-sensitive infectious diseases are routine actions developed in the context of health systems but some specific actions should be also developed. Outstanding among these are the epidemiological and entomological surveillance targeted to specific diseases and territories. These areas where outbreaks and the range expansion of endemic infections are probable, under the influence of climate, should be identified using information from regionalized climatic scenarios. All these health-protecting strategies should be included in a context of multi-sector approaches to adaptation, informed by comprehensive vulnerability assessments.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Acknowledgments

We thank Isabela Brito and Poliana Pedro for their editorial assistance.

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