Climate Change and Infectious Disease: A Public Health Issue

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When it comes to climate change, people focus on physical effects such as rising sea levels. Still, beyond the physical effects lurks a less-thought-of threat: disease. Lyme disease is one example of a climate-sensitive malady, meaning climate change alters its distribution. This variance poses a new health risk to people who are not prepared for the new exposure. Understanding how climate affects disease will lead to a better-prepared populace as the climate continues to change. This chapter will explore the relationships between infectious disease and climate change.

Introduction

In the United States the topic of human-caused climate change is the subject of great political debate. Many people recognize that certain climate events and trends are occurring; some attribute these to chance, and others attribute them to human activity. These events and trends include the rising global temperature, variations in precipitation, higher sea levels, and extreme weather events. Fewer people recognize that a changing climate has an effect on disease.

My own understanding was minimal, but in my undergraduate days I had the opportunity to dedicate some of my learning to the topic. In 2017, I was selected as an American Chemical Society student ambassador to the United Nations Framework Convention on Climate Change 23rd Conference of the Parties (COP23). This was a tremendous opportunity for me, and it opened my eyes to the international affairs involved with mitigating climate change. As a biology student, I needed an understanding of the chemistry behind climate change to realize the applied effects we see in biology, including the extinction of entire species.

Prior to the conference, I had a strong understanding of the well-known solutions, such as solar energy, biofuels, and other renewable-energy sources. I sought to build upon that understanding and ventured to various exhibits and presentations on biological effects and solutions.

While at COP23 in Bonn, Germany, I encountered many nongovernmental organizations (NGOs) and their efforts in their respective countries. I met a delegation from Niger and had the opportunity to converse in French with them. Through this dialogue, I eventually learned about vector-borne infectious diseases, such as malaria, dengue, and yellow fever. These diseases

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significantly affect Niger and other African countries. As a biology student, I already knew about the existence of these diseases, but I had very little understanding of the link between them and climate change.

My undergraduate studies included learning how living populations could be forced to migrate in order to avoid extinction. On a field study in Costa Rica, I learned of the climate change–related extinction of the Golden Toad, as well as the way local bird populations like the Resplendent Quetzal were being forced to migrate to new areas/elevations because of habitat changes resulting from climate change.

As I met groups from across the globe at COP23, I made an effort to learn about their countries and the health risks they face. Since attending the conference, I have developed an interest in learning about the relationship between climate change and disease. The knowledge I gained led me to believe it is important to communicate the relationship so that more people understand the wider implications of climate change.

Infectious Disease Background

To understand the relationships, it is important to understand the background of infectious disease. Infectious diseases can be divided into two categories: anthroponoses and zoonoses. Anthroponoses are those transmitted from human to human; zoonoses are diseases transmitted from animal to animal that can then infect humans. Both types include subcategories: direct transmission (humans/animals transmit directly to other humans/animals) and indirect transmission (humans/animals transmit indirectly through a vector/vehicle to humans/animals).

The relationships between diseases and climate change can be broken into three components: vector/host, pathogen, and transmission environment. As the climate changes (e.g., temperature or precipitation change), these three parts are impacted by the host moving to a new location or reproducing more often, or the transmission zone may expand into a new region. The frequency or severity of infectious disease is modified as a result.

Pathogens

Pathogens are agents of the disease itself. Changes in temperature, precipitation, humidity, and wind can have significant effects on pathogens. These effects result in a change in frequency or severity of the respective disease and thus are important to note as climate change is discussed from the public health perspective.

Temperature

The pathogenic aspect of infectious diseases can be significantly affected by temperature. All pathogens thrive within a specific temperature range; higher temperatures can increase the mortality rate, increase reproduction, or decrease the incubation period (*1*, *2*). Lower temperatures can lengthen the incubation period of some pathogens, resulting in higher transmission rates.

Precipitation and Humidity

Waterborne infectious diseases are most affected by the level of precipitation and humidity, given the dependence upon water for the life cycle. Heavy rains may lead to the accumulation of fecal microorganisms (*3*), and drought followed by precipitation may cause a disease outbreak (*4*). One way disease outbreak can occur in this circumstance is surface runoff. Given the dryness of the land, rain may fail to penetrate the dry and compacted soil that often accompanies drought, which as a result can contaminate crops.

Low precipitation, on the other hand, may lead to higher concentrations of waterborne pathogens (*5*). This occurs because the dilution of stream-receiving waters is reduced.

Wind

Wind affects airborne diseases the most. When winds pick up dust particles, virus transportation may increase (*6*). Viruses can be transported over long distances—even across oceans—when attached to dust (*7*). Bacteria, fungi, and fungal spore population levels have been found to be higher during dust storms in Asia (*7*). This shows that wind can play a significant role in pathogen dispersal.

Vectors

The vectors are what transports the pathogen from host to host or place to place. Changes in temperature, precipitation, and humidity can have significant effects on vectors. Pathogen hosts are similarly affected by these changes. Like the pathogens, these effects on the vectors and hosts can result in a change in frequency or severity of the respective disease.

Temperature

The distribution of disease vectors may change with temperature. As temperatures rise, low-latitude life may move to mid- or high-latitude regions. In some cases, this leads to an expansion of distributions, which is impactful on public health. Other cases, restriction of distribution may occur. Vectors may be found in new regions, which means the pathogen can now be in a new region. This can be problematic for areas that are not equipped for the pathogen.

Precipitation and Humidity

Prevalence of disease vectors may change with precipitation. Rainfall may increase vector-borne disease prevalence. Life-stage development of some vectors accelerates, causing larval development to occur more quickly (*8*). This would be important to prevalence for pathogens like malaria, which the mosquito transmits at certain life stages.

Humidity has a direct impact on the activity of disease vectors; some change distribution in order to remain in ideal humidity ranges, which may cause vectors to move into nontraditional areas. Just like pathogens, the vectors thrive in particular areas and have a preference for humidity.

Transmission

A significant amount of published information is available regarding pathogen transmission, an important aspect of infectious disease. Climate change certainly affects both indirect and direct transmission, as well as pathogen viability. When viability is altered, so is the transmission. When it comes to transmission, human and vector/host behavior has been well studied.

It is understood that human patterns themselves (e.g., lifestyles and vacations) may depend on climate. For example, people spending more time indoors may be correlated to influenza prevalence in Europe (*9*). Migrations of farmers brought the re-emergence of Kala Azar, a parasitic disease, in Brazil in the 1980s and 1990s (*1*).

Agricultural productivity changes as a result of climate change are beyond the scope of this chapter, but it is important to note that these changes may lead to malnutrition, starvation, population displacement, and conflict (*10*). In some regions, populations become displaced and conflict ensues. It is known that food insecurity can result in conflict and conversely conflict can cause food insecurity. When climate change reduces agricultural productivity and crop availability decreases, food insecurity ensues.

Extreme Weather Events

Extreme weather events, an effect of climate change, may have various impacts on infectious disease. El Niños, La Niñas, heat waves, droughts, floods, hurricanes, and cyclones are just a few examples of these events. Various types of weather events are correlated with various diseases (*10*). As an example, in 2000, the heat wave in Israel was associated with an outbreak of West Nile virus (*11*). The researchers in this study found that the virus replicated faster and became prevalent earlier because of the higher temperatures. Therefore, indirectly, climate change initiated the outbreak.

Case Studies

Although the evidence for climate change and its effect on infectious disease is significant and growing, I did not fully grasp the potential implications until I learned more about specific diseases and how climate change affects them. I focused my research on the indirect transmission of infectious diseases, specifically dengue, malaria, and Lyme disease, chosen for their global notoriety, and their relationships to climate change. Each of these is a vector-borne infectious disease and all pose significant public health concerns.

Dengue Fever

Dengue fever is a vector-borne viral disease that is transmitted to humans by mosquitoes. Currently, it affects more than one-third of the world, and it is the leading cause of illness and death in the tropics and subtropics (*12*). As of now, the recommended preventive technique is integrated mosquito control, as mosquitoes are the primary transmission vector. No specific medication for treatment exists.

In the tropics, dengue is endemic (meaning it maintains a constant baseline of infection in the region), but it is sometimes classified as an epidemic when many people are infected at once through an outbreak. Dengue is currently reported in the Americas, Southeast Asia, and the Western Pacific, with 2.4 million to more than 3 million reported cases annually (*13*). Climate change has the potential to make dengue prevalent in new regions, such as the United States, where an immunity does not exist.

Two key factors associated with the spread of dengue-carrying mosquitoes are domestic water supplies and warming temperatures, both of which are associated with elevated dengue risk and affected by climate change (*14*).

The vector for dengue fever is *Aedes aegypti*, a mosquito that lays eggs in stagnant water. The mosquitoes primarily become infected by biting a human with the virus, after which they can transmit the virus to other people.

What is intriguing to me as someone studying biology and someone concerned about climate change is the distribution of this disease over time, a point that was expressed at COP23. *Aedes* mosquitoes were found in western Europe in the early 1900s, with a wide distribution that shrank with time, a change primarily attributed to improvement in water systems and sanitation (*15*). The mosquito eventually recolonized parts of western Europe and parts of southern Russia and was brought to the Netherlands (*16*).

Historical trends show that temperature is the biggest indicator of mosquito distribution; prevalence, biting rate, early life-cycle development, and survival rate are additional factors (*8*, *17*, *18*). Precipitation, meanwhile, affects *Aedes* size, population, and behavior (*4*), with increases in precipitation levels correlating with higher incidences (*14*). In Taiwan, dengue risk was extended for up to 15 weeks after precipitation exceeded 50 mm per day (*14*).

Overall, changes in climate could affect the dengue distribution by changing where the mosquitoes are located, when they are active, or their infectious period (*19*). In addition, we see mosquito competence, biting behavior, and survival also affected.

Looking ahead, one study from Estallo et al. (*14*) used climate projections to predict that dengue epidemics in Europe could increase, accompanied by an increase in duration and transmission intensity, meaning that overall, Europe would see more epidemics. Beyond Europe, distribution is predicted to expand in eastern North America, southern South America, central Africa, East Asia, and northeastern Australia (*18*). This modeling is dependent upon greenhouse-gas emission trends; specifically, whether greenhouse gases increase at a moderate or high rate. Another projection, published by Monaghan et al., states that by 2061–2080, the land area suitable for the vector and the number of people exposed to dengue could increase by at least 8% (*18*). Other models show higher percentages but also take into account non-climate factors, such as population growth.

Dengue distribution and incidence are changing, with precipitation and temperature as the two main drivers. By affecting the vector (mosquitoes), the virus is able to impact new populations and change its effect on current populations.

Malaria

Malaria is another vector-borne disease caused by a parasite, *Plasmodium*, and transmitted by female mosquitoes from certain species of the genus *Anopheles*. Similar to dengue, mosquitoes become infected when they bite a host with the parasite; subsequent bites have the potential to spread infection.

Malaria has a high prevalence in sub-Saharan Africa, with estimates of 250–500 million cases worldwide (*20*). Like dengue, malaria is highly affected by climate. Malaria's distribution is dependent upon the distribution of its vector, the mosquito. Where the climate conditions are suitable for mosquitoes, malaria prevalence is higher.

Ideal conditions include the higher temperatures, humidity, and precipitation typical of tropical and subtropical regions. As the climate changes and these regions expand, the distribution of malaria will change proportionately. Higher temperatures, humidity, and precipitation will attract the mosquitoes. Malaria may expand into new areas and may be less prevalent in formerly occupied areas. Given climatic changes and modeling, highlands in Africa and parts of South America and southeastern Asia will be most significantly affected, that given human health there is already compromised (*21*). Other regions where malaria may spread have populations less susceptible to malaria risk.

Lyme Disease

Lyme disease, the most common vector-borne illness in the United States, holds the potential to have a direct impact on an increasing segment of U.S. and Canadian populations as the climate changes. Most cases of Lyme disease reported from 2006 to 2016 were concentrated in 14 states, primarily the northeastern United States (*22*).

This infection, caused by a bacterium, can produce a wide variety of symptoms, including rashes, fatigue, and joint pain. Even following successful treatment, there can be long-term incidents of post-treatment Lyme disease syndrome, which describes the same generalized symptoms (*23*).

Lyme disease is spread through the bite of an infected deer tick (*Ixodes scapularis*). Most cases of transmission come from nymphs, or immature ticks, which feed during the spring and summer months. Ticks cannot fly or jump, so instead they climb onto hosts who brush against the leaves, shrubs, or grass where the ticks are waiting.

Deer tick distribution is heavily affected by climate factors. It is predicted that rising temperatures will eventually cause tick distribution to expand to higher latitudes and simultaneously make southern latitudes unsuitable for ticks, so ticks will vacate southern latitudes in search of more temperate areas (*24*).

Lyme disease has spread farther north in the United States since 1996 (*24*), and the number of U.S. cases has more than doubled since the 1990s. Lyme disease prevalence is also increasing in Canada. From 1996 through 2016, Lyme disease has increased from 0.4 to 2.7 per 100,000 population (*25*). Modeling has projected the expansion of the deer tick further into Canada because of climate change (*26*).

Other Diseases

The list of other diseases affected by climate change is substantial. These include (but are not limited to) schistosomiasis, helminthiasis, river blindness, Venezuelan hemorrhagic fever, cholera, cutaneous leishmaniasis, oropouche, visceral leishmaniasis, red tide, Rift Valley fever, and hantavirus pulmonary syndrome (*1*). It is important to note that regions with fewer medical resources are generally impacted more by disease. These regions can be classified as climate vulnerable, as they are disproportionately affected by the consequences of climate change. The climate-vulnerable regions are of particular concern in regard to public health, as external support may be needed to preserve human life.

Conclusion

Climate change poses a real threat to public health. Data support hypotheses that certain diseases are changing in distribution, severity, and frequency because of climate change. Climate change is no longer an issue for just those involved in environmental policy; it is a health policy matter for all of us.

My experience at COP23 helped me see that climate change is a threat to the welfare of a great many individuals who do not realize the risk at present, and that health is underemphasized in the political discourse locally, nationally, and internationally. It will take the consistent effort of all constituents to raise awareness of the public health threat that climate change poses. With such awareness, I hope that those who still attribute climate change to chance will become motivated to become a part of the solution. Knowledge concerning the climatic effects on health is growing in the United States, as demonstrated by the many U.S. institutions referenced in this chapter. Although many academics, researchers, and medical professionals have the necessary understanding, the public at large is less aware. Once more people realize that climate change can affect public health, I predict more of the population will become motivated to become advocates.

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