Artykuł przeglądowy *Review*

Impact of global warming on the spread of infectious diseases

ANNA WIELICZKO, ZDZISŁAW STARONIEWICZ

Department of Microbiology, Faculty of Veterinary Medicine, University of Environmental and Life Sciences, Norwida 31, 50-375 Wrocław, Poland

Wieliczko A., Staroniewicz Z.

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Summary

After years of scientific and public discussion concerning a temperature rise resultant from human activity and the on-going industrialisation, the global warming has become an evident fact. The effect of the temperature rise and the climate change will surely alter epidemiological aspects of some infectious diseases. In this review, we try to analyse various data concerning the impact of global warming on the spread of infectious diseases caused by bacterial, viral and protozoan agents. Certainly, it is extremely important for veterinarians and public health that some diseases have altered in their epidemiological aspects and distribution. Some new diseases may emerge; others, previously endemic, may migrate to new geographical regions. The review is focused on pathogens important to both humans and livestock, such as malaria, dengue, bluetongue, West Nile virus, tick-born diseases and infectious diarrhoeas. There are still few scientific papers on the subject, because of numerous difficulties involved in conducting such studies, such as their long time of duration, multiple factors involved in such predictions, and complicated mathematical models containing climate and epidemiological data.

Keywords: global worming, infectious diseases, vector-borne diseases, food-borne diseases

In recent decades, increases in average temperatures of the atmosphere and oceans have been observed. According to the United Nations Framework Convention on Climate Change, the average temperature of the earth's surface has risen by 0.6°C since the late 1800s (22). It is expected to increase by another 1.4 to 5.8°C by the year 2100. The change is very rapid and profound and even if the minimum predicted increase takes place, it will be larger than any century-long trend over the last 10,000 years (21).

It is almost certain that global warming is due to human activity and excessive and uncontrolled industrial development, which has increased the emission of „greenhouse gases" (mainly carbon dioxide, methane and nitrous oxide) into the atmosphere, which in turn causes greater heat retention on the Earth's surface. Unfortunately, there is a trend for carbon dioxide emissions to grow (21).

The impact of global warming will be very broad from the environmental and the human point of view. The climate changes will result in a rise of the sea level, a decrease of biological diversity due to ecosystem changes and unification. On the other hand, extreme weather events and altered precipitation will influence agriculture and food production. These difficulties will in turn worsen the problem of human overpopulation and famine. Moreover, climatic change will have direct and indirect effects on health, both human and animal. Direct health effects refer to increased heat stress, asthma and cataracts. Indirect health effects include changes in diet and nutrition due to altered food production, and the spread of some infectious diseases, vector-borne, food-borne and water-borne in particular (2).

Vector-born diseases

Many of the infectious agents such as viruses, bacteria and protozoa are spread by intermediary organisms or vectors, usually parasitic arthropods. In some cases, a disease may be transmitted within a reservoir species without affecting humans; thus, it is endemic in a region and does not often affect humans. However, life cycles of parasites and the multiplication of pathogens are dependent on climatologic conditions. Increases in temperature usually lead to shorter development times in a vector organism along with a faster blood-meal digestion, which mainly escalates the biting frequency (5, 14). Therefore the increase in annual temperatures and changes of humidity might be affecting vector-borne diseases. Unfortunately, there are no significant studies that pay more attention to the direct impact of the global warming on the spread of vector-borne diseases.

The most important and prevalent vector-born disease in the world is malaria. Nearly 40 species of the mosquito genus *Anopheles* transmit four species of causative protozoa *Plasmodium spp*. (4). The distribution of each of the *Anopheles* species is restricted by environmental factors, and is usually much wider than the distribution of the disease. The optimal temperature range for *Anopheles* is between 20°C-25°C (14). Malaria was present in Europe in the past, but later, in the 1970's, the World Health Organization (WHO) declared this continent as free of malaria. However, malaria is now an endemic disease in 92 countries, and more than 40% of the world population lives in the risk area. This is an example of how quickly tendencies concerning vector borne diseases can change; this is of course a multifactorial process, and it depends not only on the climate change (8). As annual temperatures increase, areas suitable for malaria vectors will expand into temperate regions. The most endangered countries are those where malaria was eradicated in the past, but now have poorer health systems, such as some former Soviet republics: Armenia, Azerbaijan, Georgia, Kyrgyzstan, Turkmenistan, and Uzbekistan (15, Travelers' Health: Malaria map application: http://cdc-malaria.ncsa.uiuc.edu). This is mostly caused by the appearance of insecticide-resistant *Anopheles*, but the increase in the mean summer temperature could also be a significant factor. The latest malaria outbreaks in Asia and Africa seem to be connected with the El Niño phenomenon (15).

Another important mosquito-borne disease is dengue, caused by 4 antigenically distinct flaviviruses. In 2005, dengue was the most important mosquito-borne viral disease affecting humans, with global distribution comparable to that of malaria: it is estimated that 2.5 billion people live in areas at risk from epidemic transmission. The number of blood meals taken during the mosquito's life cycle depends on the female's weight, which in turn is temperature-dependent (14). Using computer-based stimulation analysis, scientists linked the forecasted increase in the global temperature to a dengue vectorial capacity equation (16). They noticed that the largest area change will occur in temperate regions. The epidemic potential will increase on average from 31% to 47% (according to three different global warming scenarios) for areas with an already high prevalence risk. Increased incidence will first occur in border regions.

Lindgren and Gustafson (13) proved that a higher incidence of viral tick-born encephalitis in people in Sweden was due to a combination of two mild winters and early arrivals of spring prior to the incidence year, which favoured spring development of *Ixodes ricinus* and extended its activity. In the case of the *Borrelia spp.* infection, such evidence is more difficult to obtain, because of a delayed onset of the disease in humans (chronic borreliosis as a symptom of the disease appears years after a tick bite). However, recent studies provide empirical evidence that tick phenology is associated with climate, and, importantly, that both climate and tick seasonality are associated with variation in *B. burgdorferi* genotype frequency (9).

The epidemiology of pathogens of veterinary importance spread by tick bite, such as *Erlichia spp.* and *Babesia spp.*, might also be affected by climatic disruptions altering the tick's biology and its distribution. So far, the seroprevalence of *Erlichia canis* in dogs in Poland is smaller than in southern Europe (17).

West Nile virus (WNV) is a mosquito-borne flavivirus that is a neuropathogen in humans, horses, and birds and is likely to persist in the Western Hemisphere as an endemic pathogen with periodic outbreaks. In 2002, the spread of the virus in the United States resulted in the largest epidemic of WNV encephalitis. Dohm and colleagues analyzed the effect of the incubation temperature on the ability of *Culex pipiens* to transmit the WNV. The results were evident: at the temperature of 30°C the virus was present in nearly all mosquitoes very early (4 days after blood meal), and at 18°C its presence was significantly reduced (6).

Recently the World Organization for Animal Health (OIE) identified the European vector for ruminants' bluetongue disease (caused by orbivirus) as *Culicoides dewulfi.* Earlier it was thought that the disease may only be spread by *C. imicola*, which is found in Africa. The adaptation of the virus to a specific biting midge common in Europe leads to its geographical expansion on that continent and may produce more outbreaks in the future (20).

The health of livestock appears to be in danger also due to emerging diseases (Malignant catarrhal fever, African swine fever) to which animals in the temperate climate have little resistance. Since 2007, outbreaks of African swine fever have occurred in Georgia, Azerbaijan, Armenia, and most recently Russia (OIE annotation from October 2009), affecting pigs and boars, which suggests that the disease returned to these countries after its eradication in 1977 (OIE http://www.oie.int/wahis/public.php?page=single_report&pop=1&reportid=8632).

According to World Health Organization (WHO), other vector-borne diseases which can be expected to increase their area of prevalence and potency of infection are schistosomiasis, leishmaniasis, Lyme disease, Murray Valley Encephalitis and Rift Valley Fever (10).

Food borne and water borne diseases

Exposure to water-borne and food-borne pathogens can occur by drinking water, ingesting seafood or fresh food products. Weather, especially temperature and precipitations, influences the growth and dissemination of potential microbial agents.

More than 100 types of pathogenic bacteria, viruses and protozoa can be present in contaminated water (19). Changes in the intensity of the El Niño/Southern Oscillations (ENSO) led in recent decades (1980-2001) to a seasonal increase of cholera prevalence in Bangladesh (18). Also the 1997/1998 El Nińo peak in Peru was associated with a significant increase in hospital admissions of children with severe diarrhoea (8% increase for every 1°C rise of the ambient temperature) (3). Other water-borne pathogens which were considered to increase disease prevalence because of a higher ambient temperature are *Cyclospora*, several *Vibrio* species, whereas *Cryptosporidium parvum* and *Giardia lamblia* are associated with heavy rainfalls (19). It is known that the global warming will be associated not only with a higher temperature but also with altered precipitations (droughts and rainstorms): effects similar to ENSO impact of increased spreading of some infectious disease.

The warming of oceans could favour more frequent toxic algal blooms which in turn might increase the incidence of diarrhoeal diseases and the risk of fish and shellfish toxin poisonings (1). A higher temperature produces a bigger risk of food poisoning caused by *Salmonella* and *Campylobacter* (11). Indeed, there is a positive correlation between monthly salmonellosis notifications and the mean monthly temperature (7). Moreover, the isolation of *Campylobacter* in poultry meat products and the incidence of human campylobacteriosis were shown to be higher in summer months (12).

Finally, not only known diseases, such as haemorrhagic fevers, but also new potential human and livestock pathogens may be set free by changes in the ecosystem (1).

Conclusions

The global warming is an evident fact. This phenomenon will almost certainly change the epidemiology of vector-borne, water-borne and food-borne diseases, but it is very difficult and perhaps impossible to predict to what extent the climate change will affect the spread of infectious diseases. There are numerous factors involved in such predictions.

It appears that factors such as the migration of people to urban areas combined with overpopulation and the development of aviation will significantly affect the dynamics of disease spread. Also wild animals, acting as reservoirs for numerous zoonotic diseases, might eventually migrate to other areas, because of the climate change.

It is worthwhile to mention that malnutrition and poverty, secondary to crises in agriculture resulting from the climate change, expanding deserts, lack of clean water and the intensification of food production as potential risk factors, may have detrimental effects on the health of human and animal population. Food and vector borne diseases also play an important role in the epidemiology of the climate change owing to induced alteration of various ecosystems.

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Author's adress: Anna Karolina Wieliczko, DVM, BVSc, Department of Microbiology, Faculty of Veterinary Medicine, University of Environmental and Life Sciences, Norwida 31, 50-375 Wrocław, Poland; e-mail: anna.wieliczko@up.wroc.pl