PUBLIC HEALTH

Monitoring EU Emerging Infectious Disease Risk Due to Climate Change

Climate change, globalization, and other drivers have made Europe a "hot spot" for emerging infectious diseases, which calls for changes in monitoring systems.

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In recent years, we have seen transmission of traditionally "tropical" diseases in continental Europe: chikungunya fever (CF) in Italy in 2007, large outbreaks of West Nile fever in Greece and Romania in 2010, and the first local transmission of dengue fever in France and Croatia in 2010 (*1*–*3*). These events support the notion that Europe is a potential "hot spot" for emerging and re-emerging infectious diseases (EIDs) (*4*). Major EID drivers that could threaten control efforts in Europe include globalization and environmental change (including climate change, travel, migration, and global trade); social and demographic drivers (including population aging, social inequality, and life-styles); and public health system drivers (including antimicrobial resistance, health care capacity, animal health, and food safety) (*5*, *6*). Climate change is expected to aggravate existing local vulnerabilities by interacting with a complex web of these drivers (*6*). For example, increases in global trade and travel, in combination with climate change, are foreseen to facilitate the arrival, establishment, and dispersal of new pathogens, disease vectors, and reservoir species.

Complexity is not an excuse for inaction. An effective public health response to climate change hinges on surveillance of endemic and emerging diseases (*7*). Infectious disease surveillance at the European level is regulated by the European Parliament and Council (*8*). In 2009, the European Commission outlined actions needed to strengthen the European Union's (EU) resilience to the impacts of changing climate (*9*), specifically on the surveillance of health effects such as infectious diseases. The European Centre for Disease Prevention and Control (ECDC) was charged with guiding this process, which is summarized below. It included extensive literature reviews, evaluation of current surveillance systems in Europe, weighted risk analysis of different diseases, and expert consultation with EU member state representatives (*10*, *11*).

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Novel Approaches to Risk Assessment and Surveillance Are Needed

Currently, risk analyses tend to focus on identifying diseases that are climate-sensitive. Evidence-based risk assessments with clearly defined uncertainties and underlying assumptions should be routinely undertaken to identify disease risks from climate change and to prioritize possible changes in surveillance. However, a comprehensive climate change assessment needs to be expanded to account for societal aspects so as to fully reflect the impact of climate change. The results from such combined, weighted analyses can be used to evaluate whether surveillance ought to be implemented or modified.

Current EU-wide surveillance is either indicator-based (annual country-level reporting of confirmed human cases) or event-based (detection of individual disease outbreaks through epidemic intelligence). Traditional surveillance often does not suffice for early detection of EIDs. EU member states currently report confirmed human cases of notifiable diseases to ECDC, animal cases of zoonotic diseases to other EU registries, and food-borne and zoonotic outbreaks to the European Food Safety Authority. Reporting of bathing and drinking water quality data are governed by other EU directives, and vector surveillance is voluntary. Early detection of EIDs related to climate change calls for fine-tuning of current surveillance approaches; for example, increased cross-sectoral interactions and sentinel surveillance are warranted.

Climate Change and Infectious Diseases

Notable changes in annual average temperature and mean precipitation are predicted for Europe, with disproportionately warmer winters in the north and warmer summers in the south (*12*). The impacts of climate change on infectious diseases are complex and multifaceted (*11*, *13*) (see table S1 in the supplementary materials). Changes in precipitation amounts and patterns can bring about increases in water flows and floods, leading to contamination of drinking, recreational, or irrigation water and increased risk of outbreaks of cryptosporidiosis and vero toxin–producing *Escherichia coli* (VTEC) infections, for example. Higher water temperatures increase the growth rate of certain pathogens, such as *Vibrio* species that can cause food-borne outbreaks (seafood) or, on rare occasions, lead to severe necrotic ulcers, septicemia, and death in susceptible persons with wounds bathing in contaminated waters. Elevated air temperatures could negatively affect the quality of foodstuff during transport, storage, and food handling. Increasing temperatures typically shorten arthropod life cycles and the extrinsic incubation periods of vector-borne pathogens, potentially leading to larger vector populations and enhanced transmission risks. Long-term seasonal changes will affect both vectors and host animals and may locally affect land-use changes and human behavior, with implications for the geographical distribution, seasonal activity, and prevalence of many vector-borne diseases in Europe (*11*).

Weighted Risk Analysis

EU member states are currently required to report 46 infectious diseases and 7 additional diseases if they cause hemorrhagic symptoms. In addition, nosocomial infections (i.e., hospital-acquired) and antimicrobial resistance are also mandatory to report. Of the total reportable diseases, 26 were found to be either directly or indirectly affected by climate change, on the basis of a systematic literature review and expert judgment (see the supplementary materials). Of the nonnotifiable diseases, five climate-sensitive diseases were considered to be EIDs due to climate change (*10*, *11*) (see table S1 in the supplementary materials).

Based on the literature and expert judgments (*10*, *11*), the strength of association with climate change in Europe was categorized as low, medium, or high. Yet, even a strong link with climate change did not necessarily imply the need for surveillance; prevalence, severity, and secondary complications (including human and financial

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Strength of link with climate change in Europe	Low	Medium	High
High		***Vibrio* spp.** (except *V. cholerae* O1 and O139)* **Visceral leishmaniasis***	**Lyme borreliosis***
Medium	CCHF Hepatitis A Leptospirosis Tularaemia Yellow fever Yersiniosis	Campylobacteriosis **Chikungunya fever*** Cryptospiridiosis Giardiasis Hantavirus **Rift Valley fever** Salmonellosis Shigellosis VTEC West Nile fever	**Dengue fever** **TBE***
Low	Anthrax Botulism Listeriosis Malaria Q fever Tetanus Toxoplasmosis	Cholera (01 and 0139) Legionellosis Meningococcal infection	

Potential severity of consequence to society

Weighted high risk / Weighted medium risk / Weighted low risk

Weighted risk analysis of climate change impacts on infectious disease risks in Europe. CCHF, Crimean-Congo hemorrhagic fever. Candidates for suggested changes to disease-specific surveillance are in bold. Asterisks indicate diseases currently notifiable in some EU member states but not legally reportable to ECDC.

costs for society) were important considerations in this weighted analysis. By combining these parameters, the importance of disease for society was ranked as low, medium, or high. These values were then plotted on a matrix (see the figure) to reflect the joint importance of climate change and severity of a specific disease in Europe.

Several of the climate-sensitive reportable diseases are found in the medium category. Most of these are already under adequate surveillance, even if climate change further increases disease risk, but seven could justify changes in the surveillance system (see the figure). Hemorrhagic cases of dengue fever (DF) and Rift Valley fever (RVF) are currently reported to ECDC but are all imported cases. However, increased risk of autochthonous (indigenous, not imported) transmission demands heightened surveillance.

Surveillance of EID Threats from Climate Change

The recent emergence of DF and CF in Europe has been traced to environmental conditions conducive to high vector population densities of the invasive Asian tiger mosquito, *Aedes albopictus*, and permissive temperatures for pathogen replication within the vector (*1*). Surveillance of DF and CF will require a combination of vector surveillance—to detect new risk areas and human case reporting—with a focus on the warmer parts of the year to detect autochthonous cases.

Monitoring established vectors close to their altitude and latitude distribution limits will help to delineate expanding and contracting areas of risk. Human case reporting of Lyme borreliosis could potentially be linked to sentinel monitoring of infected ticks in selected areas, a practice already implemented in the Czech Republic and planned for Denmark. Using the disease-specific skin rash, erythema migrans, as the case definition of Lyme borreliosis would pick up shifting distribution and risks, rather than the rare laboratory-confirmed Lyme neuroborreliosis. For the detection of possible new risk areas of leishmaniasis, surveillance of the sandfly vectors could be coupled with monitoring of infected pet dogs in the EU. Tick-borne encephalitis (TBE) is best surveyed through reporting of serologically confirmed human cases.

Establishing surveillance for the introduction of new vector species into the EU could contribute substantially to infectious disease control, particularly when linked with surveillance of imported human and/or animal cases. Enhanced collaboration between the veterinary surveillance and public health sector will advance preparedness and response if pathogens and vectors become prevalent in the region and pose a threat to humans. Lessons learned from pandemic avian flu preparedness could be applied to other EIDs. Collaboration between the human and veterinary sectors was considerably improved through such practices as regular meetings, routine sharing of epidemiologic and laboratory data, preparation of linked response plans for human and veterinary health, and coordinated outbreak investigations.

Important food-borne and waterborne diseases, in particular the zoonoses, are already part of surveillance collaborations in Europe. However, new collaborations will be needed. Surveillance of *Vibrio* spp. outbreaks due to seafood consumption could be enhanced by initiating collaborations between human case surveillance and laboratory monitoring of bivalve shellfish contamination.

These challenges call for the development of improved surveillance by monitoring environmental precursors of disease. ECDC is developing the European Environment and Epidemiology (E3) Network, designed to link environmental with epidemiological data for early detection of and rapid response to shifting infectious disease burden (*11*). ECDC is also developing VBORNET, a surveillance tool used for monitoring the distribution of invasive disease vectors within the EU.

Conclusions

Adjustments to existing surveillance practices in the EU, as outlined above, will enhance preparedness and facilitate the public health response to EIDs and thereby help contain human and economic costs (*14*). These benefits need to be balanced against the additional costs of program implementation; however, cost-benefit analyses tend to be hampered by the inherent difficulty in attributing EID impacts to specific climate change events. Nevertheless, these policy-driven adaptation measures should facilitate early detection of EIDs, regardless of the underlying macro-level drivers.

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Supplementary Materials

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