Climate change, globalization, and inequality: How vector-borne infectious diseases are threatening human health in Canada

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Global environmental change, driven by avertible anthropogenic catalysts that amplify greenhouse gas (GHG) emissions is the single most arduous threat facing humanity today (1). With a Climate Risk Index (CRI) of 21.83 in 2020 (2), Canada is considered one of the top 10 countries most vulnerable to a changing climate due to its susceptibility to extreme weather events from coast to coast to coast (3). In many ways, climate change is a "*crisis multiplier*" that has far-reaching implications for international peace, security, and importantly, human health (4,5). The surge and spread of endemic and exotic vector-borne infectious diseases (VBIDs) and their upshot on the health of Canadians are especially staggering and have risen in incidence by 10 percent over the last 20 years due in large part to climate change (6). Aside from environmental changes, there exist non-climate drivers of VBIDs emergence and re-emergence including changes to social, economic, and commercial indices as a result of globalization (7). With an advanced communications technology system and a society composed of culturally distinct individuals, Canada is one of the most globally integrated countries in the world (8). However, the impacts of climate change and globalization on livelihoods are not uniform in their reach, nor in their magnitude (9). In this essay, providing real-world Canadian examples, we explore the distinct roles of climate change and globalization as drivers of VBIDs transmission, risk, and burden; we address how, together, a changing climate and globalization are increasing national inequality and subsequent disparities in the VBIDs context; and finally, we lay bare the current challenges and opportunities for the Government of Canada to navigate the unequal impacts of climate change on the spread of VBIDs against a backdrop of a likewise changing, globalizing world.

Climate change as a driver of VBIDs emergence and re-emergence

Over the last decade, the Government of Canada has made national efforts to significantly reduce GHG emissions, ensuring that all sectors participate in the increasingly low-carbon economy[1] (10). However, despite these efforts, Canadians are still braving the impacts of climate change and the consequent increase in VBIDs incidence. There is empirical proof that, as average annual temperatures rise, changes in precipitation result in changes to the ecosystems that host VBIDs, making their bionomics more suitable, durable, and optimal for propagation (11,12). For instance, climate change models predict an expansion of the geographical range for West Nile Virus (WNV) into regions with higher numbers of previously unexposed human and animal hosts (13). Currently, WNV is endemic in the southernmost parts of Canada where, in the Prairies, increased water scarcity has been linked with warmer and drier summers, and temperatures that positively correlate with the development rate of its vector (14-16). Further, increased ambient temperatures are also improving tick survival, lengthening their transmission period, and expanding the range of their reservoir as evidenced in Ontario (17), where the number of Lyme disease cases in 2019 were nearly 20 times higher than 10 years prior (18). More compellingly, there is an increased risk that foreign VBIDs, having been introduced from abroad on account of globalizing forces, will become established in Canada in the coming years (19).

Globalization as a driver of VBIDs emergence and re-emergence

[1] The Government of Canada has formally updated its nationally determined contributions (NDC) under the Paris Agreement for the United Nations Framework Convention on Climate Change (UNFCCC) with the goal of reducing emissions by 40-45% below 2005 levels by 2030. Canada is steadily committed to reducing its emissions to net-zero by 2050. These goals were reiterated in the 2020 Speech from the Throne (20), and the Greening Government Strategy from the Treasury Board of Canada Secretariat (21).

International connectivity has increased on many fronts, including the flow of information, trading patterns, and cultural diffusion (7). As Canada becomes increasingly connected to the rest of the world, the movement of people, particularly into more urban regions, is escalating the risk of foreign VBIDs among Canadians, including the spread of climate-sensitive viruses such as dengue virus (DENV), Chikungunya virus (CHIKV), and Zika virus (ZIKV; 22). Global introduction of VBIDs can arise from long-distance movement of vectors, reservoirs, and populations from distant endemic regions into Canada. When the vector is already present in Canada, climate change will increase travel-acquired cases of exotic VBIDs by amplifying the natural transmission cycle and the likelihood of contact between species, and grant short-term autochthonous transmission (e.g., DENV), with the possibility of becoming endemic over time (e.g., WNV). When the vector is absent, however, and ecological restrictions prevent structurization of vectors, the impact of climate change will be limited to globalization drivers and travel-acquired cases. Canadians are avid travellers (23), thus, even in the absence of a changing climate, global movement will continue to sustain the emergence of exotic VBIDs. Incrementally, climate refugees will also contribute to the movement of people within and into Canada, as an estimated 216 million people will be displaced due to climate change by the year 2050 (24). Ultimately, whether they manifest immediately or gradually, for Canadians, the ramifications of globalization and climate change are contributing to national inequality.

Inequality and VBIDs emergence and re-emergence in Canada

Inequalities in Canada exist, are enduring and, in some cases, are growing (25,26). Some Canadians are bearing the unequal brunt of climate change exposure, proneness, and catastrophe. Regionally, those disproportionately affected by climate change are living on

coasts, in dry regions, and in the Arctic, as obstructions to agriculture, livestock, and food security are negatively impacting livelihoods (27). For instance, because of Indigenous Peoples' (First Nations, Métis, Inuit) intimate relationship with their land and their holistic views on nature, they are often first to be afflicted by climate change, in addition to the difficulties they already face, including political and economic marginalization, loss of land, and unemployment (28,29). More specifically, in the Arctic, changes in the natural environment (e.g., melting permafrost) have significant impacts on existing infrastructure, including threats to the stability of Inuit homes (30). Furthermore, that globalization is also exacerbating inequalities in Canada further adds complexity (31,32). Notably, skill-biased technological change and international trade are generating rising economic inequality, overlapped by health inequities, in Canada's larger urban centres (33). Today, Canada is one of the most urbanized countries in the advanced world, and over 80% of Canadians live in urban centres (34). Using a health equity lens will aid policymakers in learning about how, in the next decades, VBIDs, too, will disproportionately impact these same groups. For example, urban centres will be most impacted by DENV risk, and local suitability of the *Aedes aegypti* vector will be achievable by 2080 when its transmission will verge endemicity in southern Canada (35,36), disproportionately affecting climate refugees seeking medical aid and shelter in large cities. Unmistakably, the actions Canada takes today will be pivotal to deter these grim trends.

Recommendations for the Federal Public Service

At the nexus of climate change and globalization in an age of rampant inequality in Canada, there exists policy and program opportunities unlike any other for VBIDs awareness, prevention, and control. Below are a few:

I. **Increase funding opportunities for climate change and VBIDs research:** Presently, the Public Health Agency of Canada (PHAC) funds projects by organizations and institutions that tackle the intersectional problem reviewed in this essay under the Infectious Disease and Climate Change Fund (IDCCF). Other funding opportunities, however, are few and far between. We recommend that PHAC and the Federal Government of Canada increase funding, grants, and incentive programs for projects on the geospatial probing, long-term surveillance, and climate modelling of VBIDs; risk assessments on the effects of climate and non-climate drivers on VBIDs transmission; and public knowledge, attitudes, and practices regarding climate change and VBIDs using methodologies that consider associations with socio-ecological determinants of health as well as gender and human rights dimensions.

II. **Address the need for a conceptual framework:** Many of the works cited in this essay were retrieved from the April 2019 volume of the Canada Communicable Disease Report (CCDR) published by the Ministry of Health. We recommend that PHAC and the Climate Change and Health Innovation Bureau at Health Canada, alongside Environment and Climate Change Canada (ECCC), Natural Resources Canada, and the National Collaborating Centre for Indigenous Health, in a future report, address the need for a coherent conceptual framework that endeavours to recapitulate the links between climate and non-climate drivers, inequality, and VBIDs risk in Canada[2]. In a post-COVID-19 world, where Canadians are more receptive to infectious diseases messages, a user-

[2] Frameworks for the environmental drivers, globalization, and the social determinants of health exist in the Canadian context, however, none, to our knowledge, integrate VBIDs and inequality comprehensively to guide policy at the level of the government.

friendly visual representation may steer public health awareness campaigns that aim to mitigate future VBIDs burden.

III. **Incorporate a One Health approach in the National Adaptation Strategy:** In 2020, the Government of Canada committed to developing Canada's first National Adaptation Strategy (NAS) using a whole-of-society approach to combat climate change (37). However, the reports failed to address VBIDs as an adaptation theme in working group and plenary discussions[3]. Therefore, we urge that the NAS implement a One Health approach galvanized by climatologists, epidemiologists, and social scientists alongside provincial, territorial, and municipal governments, Indigenous Peoples, youth, and other key stakeholders to assemble an inclusive, multisectoral VBIDs mitigation plan that champions VBIDs surveillance, risk reduction, and communication.

Conclusively, knowledge gaps exist regarding Canada's capacity to prevent VBIDs including a lack of reputable protocols for VBIDs control programs. The need for innovation is heightened by the growing challenge of globalization. Now, Herculean efforts by the Federal Public Service are necessary to build a better, more equitable future for Canada and Canadians.

[3]In the NAS, discussions on the principle of 'Human Health and Wellbeing' focused on the health impacts of climate change (e.g., mental health), but failed to realize methods to enhance resilience to VBIDs.

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