

The Effects and Prevalence of Vector-Borne Disease as a Result of Climate Change in
High-Income in Comparison to Low-Income Tropical Cities

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Abstract

Climate change is having significant implications for the state of health of populations across the globe. Vector-borne diseases are among the many health outcomes of this global crisis, affecting most high-and low-income tropical cities. Generally speaking, high-income tropical cities are considered to have in place better adaptation mechanisms than low-income tropical cities, especially with regard to dealing with the health impacts of climate change, including the risk of malaria, dengue, West Nile virus and yellow fever. This paper, while investigating in more detail the situation of a number of high- and low-income tropical cities, identifies the most significant underlying factors that exacerbate climate vulnerability to vector-borne diseases in these cities as being specifically related to the extent of unplanned/informal settlements, population density, population size and sanitation infrastructure.

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The Effects and Prevalence of Vector-Borne Disease as a Result of Climate Change in High-Income in comparison to Low-Income Tropical Cities

Climate change stands out as one of the most significant concerns in the modern world as countries globally grapple with the ravaging implications of the issue. Tropical cities are among the most affected by the changes in the climatic conditions. This is because normal temperature variations in such settlements lie within a much smaller range than those in non-tropical cities, and fluctuations in temperature are likely to lead to significant adverse effects. This issue has been intensified by uncontrolled urbanization – specifically, the interaction of informal settlements far from structured governmental planning. Tropical climate has specific characteristics that shape the vulnerability of human beings to different health-related concerns. In the last decade alone, these cities have been at the centre of extreme weather changes, which in turn have been correlated with outbreaks of vector-borne infections. The dangers, beyond vector-borne diseases, include heat-related illnesses and physical trauma due to natural disasters. Malaria, dengue, West Nile virus, and yellow fever are vector-borne illnesses which cause fever, haemorrhaging and can even lead to death. In recent years and in some cases decades, the overall prevalence of these vector-borne diseases and the suffering they have caused has been increasing. While both high-income and low-income tropical cities experience similar effects of these vector-borne diseases due to similar biogeographically set environments, the effects on health outcomes are different. Limited resources and capacity constraints are core drivers for vector-borne illnesses having more adverse effects on low-income tropical cities. At the operational level, however, the

root causes relate to extent of unplanned/informal settlements, population density, population size and sanitation infrastructure. This desk research provides the factors of interests, the differing policies and aims and a comparative exploration of results in six specific cities, three being high-income and three being low-income tropical cities.

Vector-borne disease

There is a positive correlation between regional patterns in the climate and specific health outcomes among the people residing in such areas (Grassl, 2011). Vector-borne diseases are infections where the primary source of transmission is through organisms, and people may suffer from vector-borne infections due to contacts with the infection through a bite from arthropods which include mosquitoes, ticks, and aquatic snails (Thomson, 2014). The World Health Organization recently revealed that the number of annual deaths due to vector-borne diseases currently stands at 700,000, with more than 3.9 billion people at risk of infection (2017). Climate change may cause damage to ecosystems, which in turn results in the emergence of vectors and pathogens in the microbial ecological setting (McMichael & Ranmuthugala, 2013). Vector-borne diseases and infections tend to be caused by arthropods which benefit from warming weather and increased presence of standing water. Mosquitoes, for example, breed in areas of abundant still water and their optimum breeding temperature is high (about 25 to 30 degrees Celsius). Malaria, dengue, West Nile virus, and yellow fever are currently some of the most common vector diseases in the world. On the other hand, diseases such as tick-borne encephalitis are increasing in tropical cities across the world, as a combination of warming waters, heat, and other weather-related disasters escalate the risks on human health (McMichael & Ranmuthugala, 2013). As climatic conditions change rapidly, the rising water temperatures will eventually cause a change in

precipitation, which becomes a breeding ground for vector-borne diseases. Flooding and storm water arising from climate change impacts are increasingly affecting health outcomes of human populations (McMichael & Ranmuthugala, 2013).

Malaria

While the good news is that the incidence of malaria is decreasing, the bad news is that it continues to affect a large population worldwide. It was estimated that, in 2015, there were 212 million cases of malaria globally, resulting in close to half a million deaths that year. The incidence of malaria had fallen over the previous five years by over 20%, and mortality due to malaria decreased by nearly 30% (WHO, 2017). This can be attributed to the emergence of stronger prevention and control initiatives in developing nations, where most such incidences occur.

Dengue

The prevalence of dengue, which is spread by mosquitoes, has both increased and spread in recent decades. More than half of the world's population is at risk for dengue infection (WHO, 2017). Symptoms include headache, pain behind the eyes, fatigue, nausea, and haemorrhage. Dengue has a high mortality and disability rate. In the five years leading up to 2015, cases globally increased by 143.1% (Hotez & Murray, 2017).

West Nile virus

West Nile virus, which is also spread by mosquitoes, poses challenges given its high mortality rate and the fact that four out of five people infected with the disease show no symptoms. The infection can result in neurological problems which include encephalitis and other brain-related issues. The problems of West Nile virus are just as perplexing for high-income countries as for developing ones, with over 1,700 deaths reported from the infection just in the United States (Hotez & Murray, 2017).

Yellow fever

Yellow fever, first identified in 1900, has been rising in recent years despite preventative efforts (Monath, Woodall, Gubler, Yuill, Mackenzie, Martins, & Heymann, 2016). Symptoms of yellow fever include eye pain, fever, headache, muscle ache, light sensitivity, nausea, and vomiting. Infection is often life threatening (Monath et al, 2016). Most recently, an outbreak in Angola has had officials in many tropical countries concerned (WHO, 2016). The virus has exhibited mobility due to travel, and cases were reported in China, the Democratic Republic of the Congo, Uganda and Kenya (WHO, 2016). Unlike other similar diseases such as dengue, there is a vaccine for yellow fever.

Tropical cities

The tropics comprise the zone between the Tropic of Cancer at 23.5 degrees north and the Tropic of Capricorn at 23.5 degrees south. Tropical cities are those located in that zone, with a tropical climate (Bay & Ong, 2007). This paper addresses tropical cities that represent both high-income and low-income metropolitan areas.

Defining what constitutes a high-income and a low-income country is determined by the working definitions of the World Bank and the resulting classification (World Bank, n.d.). There are four income groupings, and these are typically applied to nations, rather than cities: low, lower-middle, upper-middle, and high (World Bank, n.d.). These categories are based on Gross National Income (GNI) on a per capita basis. The original determination of a low-income city in the late 1980s was a GNI of \$6,000 US dollars per person using the Atlas method (World Bank, n.d.). High-income countries are based less on calculation of economic status and more on recognition and tradition as an Organization for Economic Cooperation and Development (OECD)

member (World Bank, n.d.). Lower and upper middle income refers to countries which are not low enough in their GNI to qualify as low income, but not high enough to compare with the traditional OECD nations (World Bank, n.d.).

Consistent with that definition, this paper covers three high-income tropical cities: Darwin, Miami and Singapore; and three low-income tropical cities: Bali, Mumbai and Port-au-Prince.

Miami, United States

While Miami is located just north of the Tropic of Cancer, it experiences a tropical climate. In the United States, cities like Miami have consistently emerged from significant weather-related destruction without the population experiencing adverse health related concerns such as the risks of vector-borne diseases (Leibler et al., 2016). Miami benefits from financial resources and health infrastructure of the state and nation which support the management of the well-being of residents as well as the control and containment of outbreaks when they do occur (Kitron, 2016). With a population of just 453,000, this city is much smaller than others in the comparison, although not as small as Darwin in Australia.

Port-au-Prince, Haiti

Haiti is located south of the Tropic of Cancer, in the Caribbean Sea. There are only about 700 miles between Miami and Port-au-Prince, the capital of Haiti, but they are worlds apart in terms of capacity and ability to respond. The city has a population of approximately 1 million people, with nearly 2.7 million residents if the surrounding region is included. Low-income Caribbean countries and cities within them such as Port-au-Prince have seen a significant increase in malaria, dengue, West Nile virus and yellow fever and related mortality due to the inability to adequately deal with the ravaging implications of vector-borne diseases (Perkins, 2001). In the case

of Haiti, the spread of disease after natural disaster was significantly related to the lack of critical infrastructure for wastewater management (Raila & Anderson, 2017). Earthquakes, hurricanes and other natural disasters over the past decade have resulted in increased incidence of West Nile virus, cholera, and other vector-borne and communicable diseases. Dengue has increased many times over in that time (Hotez & Murray, 2017).

Singapore

Singapore is an island, a city and a nation in Southeast Asia of over 5.6 million individuals. Singapore is relatively well off in comparison to its neighbouring countries such Malaysia and Indonesia, and it has no informal settlements. As a small island nation with a high level of education and scientific literacy, there is considerable awareness of the problems posed by climate change. A 2007 outbreak of dengue in the city was devastating, and the result was increased prevention initiatives and stronger monitoring by Singapore's National Environment Agency (Campbell-Lendrum, Manga, Bagayoko & Sommerfeld, 2015). Singapore's climate action plan includes reference to a particularly innovative technology: *Wolbachia* technology. *Wolbachia* bacteria occur naturally in over 60 per cent of all insect species, including some mosquito species. Studies have shown that when a male mosquito carrying the *Wolbachia* bacteria mates with a female mosquito that is not a carrier, the eggs produced by the female do not hatch, thereby reducing the population of the *Aedes aegypti* mosquito over time, a prominent dengue vector.

Mumbai, India

Mumbai is just south of the Tropic of Cancer. This city is located in India, which while considered a low-income country for decades was recently reclassified as a lower middle income country (Somvanshi, 2016). Mumbai is one of the world's largest cities, with over 18 million res-

idents. A large population lives in informal settlements. This city suffers in particular from malaria due to bites from infected mosquitoes and rodents. Poverty and poor living conditions result in layers of risk and dangers relating to vector-borne disease that can make a population more vulnerable to such diseases (Kouadio, Aljunid, Kamigaki, Hammad, & Oshitani, 2012). While India does not have a National Action Plan in relation to climate change adaptation thus far, the Maharashtra state adaptation action plan includes plans to develop and maintain a digital health database for climate-sensitive diseases, including vector-borne diseases, as well as to prioritize districts with a concentration of tribal populations where malaria is prevalent. Also there are plans in place to increase investment in health research on the identification of links between temperature and rainfall increase and incidence of vector-borne diseases.

Darwin, Australia

Darwin is the largest city in Australia's Northern Territory; however, it is in a fairly remote part of the country. The population is just over 106,000, and it is therefore just a fraction of the population of the cities being compared. Monitoring for vector-borne diseases is the responsibility of the Ministry of Health of the Northern Territory. Most of the communities in this area are populated by Australian aboriginal people, and the infrastructure is weak in comparison to more populated cities on the south coast. Monitoring of diseases includes testing of animals to identify the presence of disease, even when there have been few signs in the human population (Shapiro et al., 2017).

Bali, Indonesia

Bali is an island in Indonesia which is home to 4.3 million people. Indonesia is a

developing nation; however, it has been rapidly establishing increased capacity in the provision of health care. Hospitals serve the primary care needs of inhabitants, as well as fulfilling surveillance needs for population health to serve government interests (Halstead, 2010). There is a large population living in informal settlements and with less access to government programs which could increase inhabitants' vulnerability to negative health outcomes of climate change.

Settlement Factors

In comparing the cities addressed in this paper, settlement patterns and changes emerge as an essential factor that impacts on the risks and outcomes of vector-borne diseases arising from climate change. The effects of climate change are compounded by tensions and pressures caused by the swiftly growing population in a world that has created a strain on the environment and an alteration of the natural earth system

The threat of climate change on tropical cities is premised on the reality that most of these cities are set on low-lying geographical areas that make such cities vulnerable to the effects of floods and sea level rise, particularly in light of their proximity to water bodies. The risks of warmer oceans or rising sea levels directly affect the human population in such locations. Most of the tropical cities host significant numbers in their communities due to the gradual growth in economic viability, which further complicates the ability to deal with the concerns regarding climate change. The impacts of climate change on the tropics may be significant as the signs of extreme weather become ever more notable. Within the tropics, studies have already revealed that people living in low-income tropical cities will likely suffer the consequences of climate change and the resultant vector diseases more than people living in the high-income tropical cities (Aerts and Botzen, 2014). The most common concern that may worsen the burden of vector-borne diseases

in low-income tropical cities has been found to be settlement patterns. In most of these low-income tropical cities, about 30% of the total populations live in informal settlements that comprise shacks that present a breeding ground for vector-borne diseases.

The primary challenge of dealing with infectious disease in such informal settlements is the concern related to control. The need to adopt countermeasures in dealing with the difficulties of vector diseases in such settlements is made complex by the problem of low income, illiteracy, and lack of adequate funding by the local governments. Controlling the effects of vector-borne diseases in such cities presents logistical and funding-related challenges that are not common in the high-income cities. The need for funding is an indication of the inadequacies that exist in most of the low-income tropical cities' capability to deal with the concerns of outbreaks that may lead to massive losses of civilian lives. For this reason, low-income tropical cities may remain at the frontline of human-induced changes to the climate that are currently the leading causes of vector-borne disease (Rasgon, 2015). This is particularly true given that the population of low-income cities is growing faster, and has a greater proportion of youth and children than that of high-income cities.

Policies

Health, health care, and climate change are dramatically affected by policies and settlement patterns which impact on each city. The difference between high-income tropical cities and low-income tropical cities is based on the differences in wealth distribution, infrastructure, population health programs and plans and the extent to which the citizens have information regarding the dynamics surrounding vector-borne infections.

Adaptation plans

There is considerable difference between high-income and low-income tropical cities regarding adaptation planning and the ability to implement them. It is interesting that the most extensive adaptation plans and policies are found outside of equatorial and tropical regions, for example in cities such as Birmingham, Cape Town, and Toronto. Assessment of plans for adaptation to climate change is a developing area of investigation. There is evidence that only 15% of cities globally have adopted adaptation initiatives, and less than 20% are developing city-level policies to support adaptation to climate change. Singapore is considered to be a moderate adapter, with over 15 climate change adaptation initiatives at various stages of implementation. Low-income cities are also developing adaptation plans and making policies intended to mitigate the potential impact of climate change and accompanying problems such as vector-borne disease (Araos et al., 2016).

Monitoring and tracking

While more prosperous tropical cities have made significant gains in the development of climate and health information system, low-income cities are still grappling with funding other logistical priorities related to the development of technology-based health infrastructure (Bueno-Marí 2013). There is a lack of health care and population health oversight in the programming and planning of tropical cities in the absence of adequate resources, which makes them less able to track changes in the geographical distribution of vector-borne diseases (United Nations, 2017). Prosperous tropical cities have been able to develop specific measures to detect the various emergent vector-borne infections and the possible implications of the economic and the social setting within the city. The level of preparedness has helped well-off cities to be in control of potential adverse effects of vector-borne diseases on the populations. For example, Miami has benefitted

from federal initiatives to deal with the effects of West Nile Fever beginning in 1999, which have substantially reduced prevalence and incidence (Kortekaas, Ergönül, and Moormann, 2010). The United Nations (2016) report on human health adaptation confirms that little or no funding at all for measures that aim to deal with the issue of adaptation in most low-income tropical cities is a critical concern in the process of coping with vector-borne diseases. The United Nations also affirms that indeed, there have been specific underlying challenges in the process of implementing adaptive tools in the advancement of approaches to deal with the consequences of climate change, and these are related to infrastructure and living standard.

Infrastructure and lifestyle

There is a need to also look at issues and factors that facilitate climate change adaptation strategies. However, these go to the heart of problems in developing nations, generally including water and other infrastructure as well as public health programs. Without running water, populations tend to have to collect rainwater, providing a significant surface area of standing water for the breeding of mosquitoes and other carriers of vector-borne diseases. Furthermore, a lack of running water is typically a feature of areas that also do not have appropriate drainage or flood mitigation plans, increasing the damage to property with ill-effects to health and human life.

While pessimists refer to the large population living in the informal economy and substandard living conditions as part of the problem of the “planet of slums”, there are activities in Mumbai and other large cities which are intended to transform informal settlements through survey, documentation, microfinancing, and even land titles (Davis, 2006). This may be the most promising approach to preventing the transmission of vector-borne illness in population dense, unsanitary settings, by removing the problematic factors.

Analysis

Higher-income cities are better equipped, not only because they have financial resources at their disposal to fight epidemics and prevent their spread, but also because of advantages relating to standard of living such as running water and modern wastewater infrastructure. A further advantage is that the higher-income cities are far less dense in population, have smaller populations than the lowest-income cities, and have few to no informal settlements within their boundaries. The response to vector infections between low-income and high-income tropical cities is different. This is because authorities struggle with many more complications in order to deal with the containment and aftermath of epidemic diseases in low-income countries that lack the infrastructure for monitoring as well as the treatment needed for affected persons (Frank, Schöneberg, & Stark, 2011). In both high-income and low-income tropical cities, as with other mosquito-borne illness, the response has been the promotion of ensuring that there is no standing water on a person's property. Not only does this not consider the need for water collection in developing countries, particularly during dry seasons, often municipal authorities themselves are unable to deal with standing water which breeds mosquitoes on public property. Widespread spraying for mosquitoes has become the solution of choice across both types of tropical cities.

High-income cities, such as Darwin in northern Australia, are able to benefit from significant infrastructure and resources at the national level. The city also has the advantage of the implementation of low-cost early warning systems concerning disease by testing animals such as dogs for the presence of vector-borne illness. This is a process which may be replicable across low-income cities as a means of monitoring populations and potentially putting plans into action before there is an epidemic.

There are high hopes that the youth in low-income tropical cities – a sizeable proportion of the population in comparison to high-income countries, and a large population in its own right – can leverage higher levels of education and technology to develop a new generation that is able to better deal with problems of infrastructure, particularly sanitation and housing issues. It is essential that this occurs, given the potential increased levels of warming and risks of vector-borne diseases.

Conclusion

High-income cities and low-income cities differ in their approach to dealing with possible increased vector-borne illness as a result of climate change, mostly at the cause of difference in financial resources to respond, proactive adaptation planning, and the level of complications resulting from lack of adequate infrastructure related to water and public health. Dealing with the causes of these complications provides a more robust and proactive way of approaching the problem in low-income tropical cities, and these causes include the extent of unplanned/informal settlements, sanitation infrastructure and demographic factors such as population density, age distribution. There are some success stories regarding the planning and actions that were taken by low-income cities, notably the reduction of mosquito breeding through various health promotion campaigns, and increased monitoring and treatment. However, many such cities require more assistance to modernize water and wastewater infrastructure in particular. This would help to avoid devastating complications from natural disasters and difficulties which are predicted to arise as a result of climate change.

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