Urbanisation, climate change, and leptospirosis: environmental drivers of infectious disease emergence

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Introduction

Leptospirosis is the most common bacterial infection transmitted from animals to humans, and has been identified by the World Health Organisation as a neglected tropical disease, requiring further research into its epidemiology and global disease burden. It is geographically widespread, with an estimated 300-500,000 severe cases each year and fatality rates of up to 30% (WHO 2003).

A wide variety of animals including rats, other rodents, livestock, and domestic pets have been shown to harbour *Leptospira,* the bacteria responsible for leptospirosis. Humans can be infected through direct contact with animals, or through exposure to an environment that has been contaminated by animal urine (WHO 2003).

Leptospirosis provides an important example of an infectious disease influenced by the interaction between humans, animals, and the environment. Climate change may alter these interactions in such a way as to drive an increase in the frequency and intensity of infection and outbreaks.

Background

For a city to be sustainable, the health of its inhabitants is of paramount importance. With the unprecedented growth and spread of human population, and our unrivalled ability to alter and exploit the environment, it is necessary to assess the impact of our lifestyles on the ecosystem, and for urban planners and managers to consider the close links between ecology and health (McMichael 2001a).

Infectious diseases, including leptospirosis, contribute significantly to illness around the world, and are responsible for over 50% of deaths in less developed countries (McMichael 2001b). An infectious disease is defined as *emerging* if it is newly described, expanding into a new region or habitat, increasing in incidence, increasing in its severity or duration, or increasing in its resistance to treatment (Aron & Patz 2001a). Ecological changes play a major role in the emergence of infectious diseases, and urbanisation has been associated with outbreaks and emergence of many infections around the world.

The world's population is expected to increase from 6.7 million in 2007 to 9.2 billion in 2050. The number of urban dwellers is expected to almost double from 3.3 to 6.4 billion during this time, with most of the increase occurring in less developed countries (United Nations 2008).

This massive urbanisation in developing countries has significant public health implications, including the emergence of infectious diseases transmitted through air or water, as well as those transmitted by insects and animals. The impact of these diseases will be compounded by the inadequate infrastructure and poor healthcare systems available to cope it (Aron & Patz 2001b).

Environmental drivers of leptospirosis

Environmental factors shown to affect the epidemiology of leptospirosis include heavy rainfall and flooding, high temperatures, exposure to animals, poor sanitation, and poor waste disposal (Levett 2001; Maskey *et al*. 2006; Vanasco *et al*. 2008). With global climate change and urbanisation, many of these major risk factors are expected to occur with greater frequency and intensity (Patz & Kovats 2002), potentially leading to an upsurge in the incidence of leptospirosis and the frequency of outbreaks, particularly in combination with the urbanisation trends described above.

Urban slums in tropical developing countries are at particularly high risk for leptospirosis outbreaks due to the combination of frequent flooding, warm temperatures, poverty, high population density, poor hygiene standards, poor sanitation, inadequate sewage facilities and waste disposal, poor drainage, and the abundance of rats that transmit the bacteria. When these conditions occur in small islands, the burden of disease is likely to increase for many of these reasons, but exacerbated by rising sea levels and increases in surface temperature. Small island states are also highly vulnerable to the effects of natural disasters such as *flooding*, due to their small physical size, remoteness, limited natural resources, delicate ecosystems, high population density, poor infrastructure, and limited financial and human resources to respond to the disasters (Ebi & Schmier 2005). Islands therefore offer a particularly appropriate environment in which to conduct an environmental study on leptospirosis.

Apart from its direct effects on the health of individuals, leptospirosis can affect sustainability in many ways. There are direct and indirect economic costs of disease outbreaks including the cost of health care for the acute illness as well as management of long-term medical complications; the implementation of public health services; and the loss of income as a result of the illness. During epidemics, thousands of people can potentially become infected in a short time, and inundate health care facilities. There are also potential long-term financial and social impacts on the victims' family and their community. Most outbreaks occur in urban slums, where some of the world's most powerless and vulnerable people live, and where access to health care is limited. These circumstances combine to create an environment in which leptospirosis will have the greatest health and socioeconomic impacts on communities. Furthermore, leptospirosis can threaten livestock, thus compounding economic losses. On a larger scale, leptospirosis can also affect biodiversity by its effects on wildlife populations.

Causes and effects of flooding

Flooding is the most common natural disaster around the world, and is expected to occur with increasing frequency as a result of global climate change and extreme weather events (Patz & Kovats 2002). It results from the interaction of rainfall, surface run-off, evaporation, wind, sea level, catchment size, and local topography. Urbanisation, dams, water management practices, land use, deforestation, and agricultural practices are therefore also relevant because of their impact on the above factors (McMichael, Woodruff & Hales 2006). Large cities are particularly prone to floods due to the combination of large paved, compacted, or roofed areas that are more impermeable than vegetated land. They can also create their own microclimate and cause intensification of rain, hail, and thunderstorms (Kovats & Akhtar 2008). For cultural and economic reasons, they are often situated near the coast or rivers, thus compounding their risk of flooding.

Flooding can increase the risk of leptospirosis by changing the interactions between the bacteria, humans, animals, and the environment. Severe flooding has recently emerged as a major driver of epidemics around the world (Easton 1999; Ko *et al*. 1999; Maskey *et al*. 2006; Pappachan, Sheela & Aravindan 2004; Vanasco *et al*. 2008). Apart from displacing people from their homes and increasing their environmental exposure to pathogens, flooding also disrupts animal habitats and behaviour, and provides conditions favourable for the survival of the bacteria in the environment. Furthermore, flooding can damage water and sanitation networks and disrupt health services (Schultz, Russell & Espinel 2005), thus increasing both the frequency and severity of infections.

The ecological links between leptospirosis and the environment are illustrated in Figure 1.

Proposed Research aims and questions

My research will examine the effects of extreme climate events on the epidemiology of human leptospirosis. The aim is to test the hypothesis that an increase in the frequency of flooding in centres of high population density will result in an increased disease burden from leptospirosis.

The study will aim to provide an evidence base for reducing disease burden from leptospirosis by improving our understanding of the environmental drivers of the disease, and making recommendations for adaptation to climate change that will minimise the impact of flooding on the emergence of this disease. To this end, a field study will be conducted to examine the ecological relationship between flooding and leptospirosis.

The proposed field study will be based in American Samoa, where leptospirosis was first identified in 2003. A

study in 2004 showed that 17% of adults had evidence of previous infection, and a fatality rate of 30% was reported (Winger 2004). There are many unanswered questions regarding leptospirosis on the island. We do not understand the reasons for its emergence, whether it had recently been introduced to the remote islands, or whether it been present for a long time but emerged in humans due to some ecological shift e.g. climate change such as rainfall, temperature, and flooding; environmental changes such as land use, agricultural practices, and management of waste and sewer; changing demographics such as population density and distribution; changes in population and behaviour of animal reservoirs including rats, pigs, and dogs; and cultural changes such as increasing ownership of pigs.
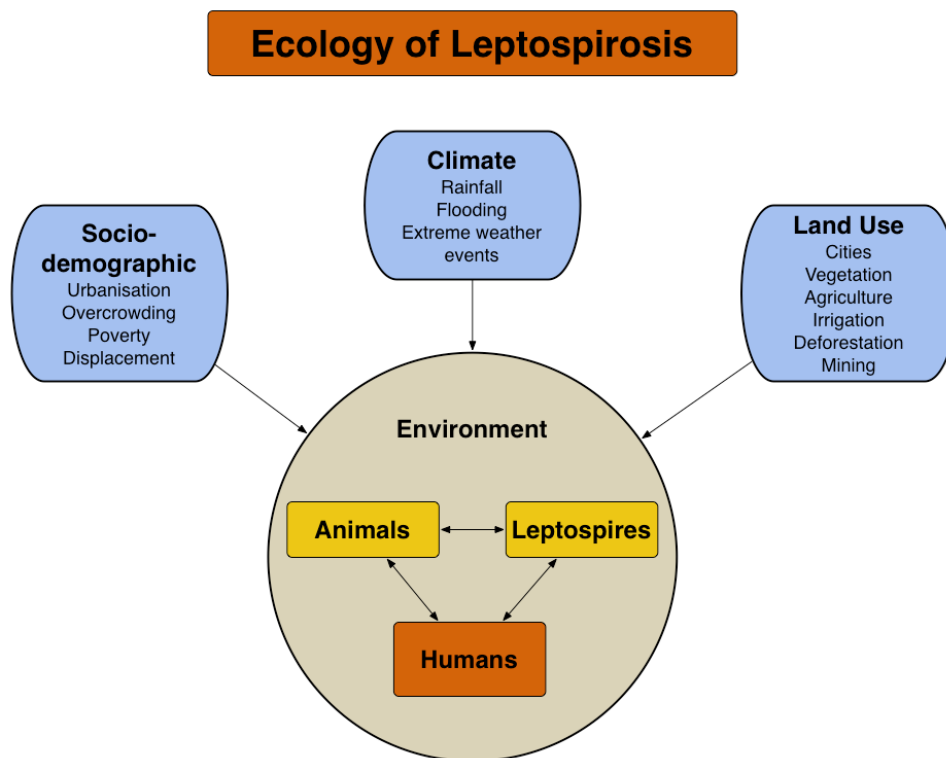

Figure 1. The Ecology of Leptospirosis

Research design

Three main sets of data will be collected to gather information on risk factors on individual, community, and regional levels.

Cross sectional seroprevalence survey

Villages will be selected across the island, and blood samples will be taken to assess infection rates of its inhabitants. There is a wide range of topography in American Samoa including beaches, rugged hills, valleys, lagoons, rivers, and mangroves, which lends itself to the assessment of various environmental risk factors at a community level.

Case-control study

Questionnaires will be used to collect data on demographics and assess behavioural risk factors on an individual level. This will include information on occupation, recreational activities, and exposure to animals, soil, surface water, and flooding.

Geographic Information System (GIS) mapping

Secondary data will be obtained on climate, topography, vegetation, land use, soil types, and population

density. Other layers of information might include historical census data; demographic data collected during routine household surveys on the island; information on recent disease outbreaks; geographic location of piggeries; data on rodent density; location of waste disposal sites; and surrogate markers for biodiversity.

GIS mapping will be used to demonstrate differences in disease *prevalence* and *distribution* around the island; correlate *environmental risk factors* with infection rates; estimate *current disease burden* based on the above, and population distribution around the island; identify *environmental trigger factors* for disease outbreaks; and *predict future disease risk and disease burden* as a result of changes in environmental and climatic risk factors including the frequency and severity of flooding.

Research Outcomes

In American Samoa:

The study aims to generate practical information for public health authorities to reduce disease burden by directing interventions at different levels:

1. *Individual behaviour modification:*

    i. Avoidance of activities associated with a significant risk of infection, e.g. swimming in creeks after a recent flood, or walking barefoot.

2. *Community level risk management:*

    i. This might include recommendations on waste disposal, rodent control, management of piggeries, or improvements in storm drainage.

3. *Regional level risk management:*

    i. Known environmental triggers of disease outbreaks can be used as early warning systems for communities, clinicians, and public health authorities.

    ii. Quantify the risk attributable to significant risk factors, and determine the most cost-effective allocation of public health resources to prevent and control the disease.

    iii. Determine disease burden attributable to leptospirosis, and recommend appropriate resource allocation for prevention and control.

    iv. Planning of public health strategies based on predictions of future disease risk and burden as a result of changes in environmental and climatic factors such as flooding.

Wider applications:

Information generated from this research could also potentially be useful in other similar environments, such as other Pacific Islands or tropical small island states.

Environmental risk factors and triggers for outbreaks identified in the study can be used in disease modelling to determine and project locations with high risk of infection, hotspots of epidemics, and areas most susceptible to a high disease burden. This information could then be used for the planning of health services, development of early warning systems for outbreaks, allocation of disaster management resources, strengthening of infrastructure, and targeting interventions aimed at reducing infection risk as well as the overall burden of disease from leptospirosis.

Conclusion

The epidemiology of leptospirosis is complex and varies significantly in different environmental settings. Its transmission dynamics can be influenced by climatic events, environmental factors, animal reservoirs, human demographic and social trends, as well as cultural and anthropological factors. A better understanding of this disease will benefit from interdisciplinary research involving epidemiology, public health, medicine, veterinary science, laboratory medicine, demography, sociology, anthropology, climatology, ecology, environmental science, water management, architecture, and engineering, particularly in collaboration with research teams from countries where leptospirosis is common and responsible for significant disease burden.

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