

Limiting the spread of communicable diseases caused by human population movement

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Introduction

Human population movement (HPM) is a term that encompasses a variety of ways that people travel from one area to another. Population movement has historically contributed to the spread of many infectious diseases that have left their mark on human growth and progress. Illustrative examples of this are the plague in medieval times or the advent of measles in the New World. Wilson (1995) recalls when the population of Mexico was estimated to have dropped by one-third in the decade following exposure to European explorers due to new communicable diseases in a naïve population. These diseases decimated the relevant populations upon introduction since there was no prior exposure or immunity.

The current extent, speed and volume of human population movement are unprecedented in history. Mankind is a particularly potent agent of ecological and environmental change and the current extent of human mobility has vastly contributed to the spread of infectious agents and communicable diseases. Humans travel for a variety of reasons and causes. The understanding of these factors is the first stage in controlling the development and spread of communicable diseases.

This article aims to examine the pressures underlying human population movement and develop a conceptual framework of how to predict the possible spread of communicable agents and how to anticipate its effects. It will also discuss the ways in which surveillance systems can be initiated to counter outbreaks associated with infectious diseases.

Typology of human population movement

New patterns of HPM have aided the rise of new infections and help disseminate known ones. In their review of the effects of HPM on the spread of malaria, Martens and Hall (2000) outlined a variety of ways in which to describe the typology of population movement to help understand it.

Push and Pull factors

The factors underlying HPM can be classified as those that either "push" the population from the existing location, or "pull" them to a new destination. Examples of push factors are armed conflicts, environmental degradation, natural disasters, poverty, drought and famine. Examples of some pull factors are better economic opportunities, better social opportunities, protection from natural disasters and armed conflict (security) and political stability. Push and pull factors can operate simultaneously to initiate and sustain HPM.

Temporal dimensions

HPM can also be defined by its temporal and spatial dimensions that enhance understanding of communicable disease exposure and risk. Martens and Hall (2000) have delineated the temporal dimensions of HPM into 'circulation' and 'migration'. Circulation is defined as a variety of movements that are usually short term and cyclical, and which do not involve a long-standing change in residence. Migration is defined as a permanent change of residence. The following points outline the division of different types of cyclic "circulation" factors and arbitrary temporal definitions.

Circulation

Daily	Leaving place of residence for up to 24 hours (e.g. commuting, trading, and cultivation)
Periodic	Period varies from 1 day to 1 year but usually of shorter duration than seen in seasonal circulation (e.g. trading, pilgrimage, mining, and tourism)
Seasonal	Period defined by marked seasonality in the physical or economic environment (e.g. fishing, labouring, and pastoralism)
Long-term	Absence from place of residence for longer than 1 year (e.g. urbanisation, colonisation, and traders)

Migration

Long-term Population movement resulting in a permanent change of residence. (e.g. urbanisation, refugees, and colonisation)

Spatial dimensions

HPM also has spatial features that can be used to describe typology. Using malaria as a model, Martens and Hall (2000) have defined these as being either active transmitters or passive acquirers. For conceptual purposes in a general communicable disease setting, a more useful method would be to classify these dimensions in terms of the immunity of the affected person and/or the population under consideration in their original place of residence. This allows for assessment of risk in their new place of residence, namely:

Previous exposure/immunity	-	eg Measles
Previous exposure/no immunity	-	eg Old infection with Dengue Fever
No exposure/immunity	-	eg Active or passive immunisation
No exposure/no immunity	-	eg Smallpox, Malaria

(For the purposes of the classification, it is assumed that immunisation does not entail "exposure to an infectious, naturally-occurring agent").

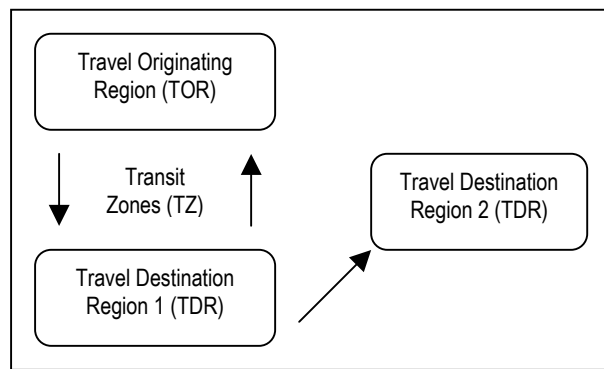
From the above definitions, it is evident how the communicable disease risk profile of a relevant individual or population can be more clearly understood by assessing the nature of population movement. A new concept will now be introduced to provide a simple yet powerful model to further clarify risk profile. This is based on 'Geographical Tourism Systems' (Leiper 1995), which is used in whole tourism system analysis in tourism management, but the principle can be readily adapted to use in a public health and infectious disease setting.

Geographical dimensions

Figure 1 depicts an adapted model that enables the study of a communicable disease risk profile based on different geographical profiles.

The essence of a Basic Tourism Model is that any journey can be thought of as a system, and is made up of three basic elements - the "Travel Originating Region" (TOR), the "Transit zone" (TZ) and the "Travel Destination Region" (TDR). Any journey can be divided into a single set, or a series of sets, of elements of this system. This Geographical System is pictorially represented in the Figure 1 below.

Figure 1: Geographical model of human population movement (adapted from Leiper, 1995).



As mentioned, the above model can serve when there is a single TDR and can also be used when there are multiple TDRs and TZs. The strength of this model exists in its ability to be applied to whatever aspect of the communicable disease is being investigated and allow incorporation of travel times to ascertain possible exposure incubation periods.

Using malaria as an example for determination of risk profile, the geographical model analysis allows determination of risk by addressing the following aspects in each element.

TOR	<ul style="list-style-type: none"> • Was initial place of origination in a malaria endemic region? • If so, were there any signs of particular drug resistance?
TZ	<ul style="list-style-type: none"> • Did the route of movement through the Transit Zone bring the population through an endemic region? • If so, how long were they in that region? • Would this exposure period be sufficient to allow human-vector contact and incubation of the malaria parasite? • What is the drug resistance profile in the locality? • Did the route take the population through mountainous or lowland/geographical features that may have increased risk of developing malaria (e.g. stagnant water reservoirs)
TDR	<ul style="list-style-type: none"> • Was the new place of residence (Destination Region) an area of a higher endemicity than in the originating region? • What is the drug resistance profile in the new region.

An example illustrating the above concept is that of refugee movement. Davis et al (1992) described the movement of Khmer refugees in 1979-1980 who travelled from the same TOR - the central valley of Kampuchea where malaria transmission is low, into Thailand. Prevalence rates of malaria, for essentially the same population, at the two main Thailand camps (essentially the same TDR) differed markedly. The prevalence at the Sakaeo camp was 39% while the rate at the Khao I-Dang camp was 4%.

Closer investigation of the route of movement of these populations revealed the following. Those refugees arriving at the Sakaeo camp came via a TZ that took them through mountain regions where malaria was endemic throughout the year. Those refugees that arrived at the Khao I-Dang camp used a TZ that remained within areas of low malaria transmission.

Malaria was the major cause of mortality at the Sakaeo camp during this time. Analysis using the above geographical model would have allowed a determination of a higher risk profile for a specified population travelling through the mountains. This in turn would have enabled workers at the Sakaeo camp to be better prepared to manage malaria in the population as well as allowing more efficient allocation of resources to the higher risk population. Employing the above predictive model would have enabled a more efficient management of malaria at the refugee camps and hopefully resulted in a decreased morbidity and mortality.

Human population movement and spread of communicable diseases

HPM can favour the spread of communicable diseases through numerous mechanisms, but can fundamentally, be broken down into four major methods:

- Ecological change and agricultural development causing conditions favourable for increased human-vector contact
- Providing the means for dissemination of organism and/or resistance
- Breakdown of public health measures
- Alterations in human behaviour

Ecological Change and Agricultural Development

Ecological factors caused by alterations to the environment precipitate the spread of communicable diseases by interspersing a susceptible human population in proximity with a natural reservoir or host to which they often have had no previous exposure or immunity. Vector and host populations can also exist in equilibrium until a climate or environmental change causes an equilibrium shift resulting in emergence and spread of disease (Jacobsen 1994). HPM is a potent cause of environmental change. Intrusion of humans into new vector habitats

- Factors that increase vector breeding sites, especially when in proximity to human habitat - eg dams, irrigation and changes in water ecosystems
- Deforestation with exposure of agricultural workers to new arthropods
- Unregulated urbanisation with poor sanitation and housing, inadequate hygiene and sewage and stagnant water supplies - all causing increased vector breeding and increased human-vector contact
- Flood/drought, famine and climate changes causing changes in ecological status and vector behaviour

Some examples by which HPM influences ecological change, or vice versa, causing communicable disease emergence and spread are noted by Jacobsen (1994), Morse (1995), Wilson (1995) and Martens and Hall (2000).

Argentine Haemorrhagic fever

Caused by infection with Junin virus as a result of agricultural changes (changing of grasslands into maize cultivation) that brought the human population into closer contact with the rodent that was the natural host for the virus.

Korean Haemorrhagic fever

Caused by Hantaan virus. Transmitted by rodents in rice fields and infection of populations are usually seen with agricultural expansion of rice fields, with infections occurring predominantly during rice harvest time.

Lassa fever

Can arise due to rapid and unchecked urbanisation favouring the rodent host and increasing exposure.

Rift Valley Fever

Outbreaks in certain parts of Africa have been associated with hydrologic alterations in building of dams and possibly periods of heavy rainfall.

Malaria, Dengue fever and Dengue Haemorrhagic fever

Can all be spread because of stimulation of mosquito breeding sites in stagnant water or in expansions of standing water.

Japanese encephalitis

Was discovered for the first time in Northern Australia in the Torres Straits in 1995 and was believed to have been driven by the very close proximity of domestic pigs, mosquito breeding sites and human habitation (Mackenzie et al 2001).

Dissemination of disease and/or resistance

HPM has historically been the main source of epidemics. War, exploration, trade and religious pilgrimages have all facilitated the spread of many diseases into isolated human populations that had evolved with a relatively small gene pool and no previous exposure to the relevant infection (Wilson 1995). HPM was essential in the spread of the plague via the dissemination of its animal reservoir (rodent) and vector (flea).

In modern times, all the above modes of HPM remain with us and still are methods by which disease can be spread. While human populations are no longer as isolated and as vulnerable as in the past, disease and epidemics still arise when there is travel into a non-exposed and non-immune population. The advent of global travel has not only increased the frequency and intensity of HPM, it has allowed the spread of many diseases at a rapid rate. Given the speed of travel, it is possible that an infected source can travel the globe within the incubation period of the relevant communicable disease causing an exponential increase in contacts.

Refugees, displaced populations and illegal/legal workers can all bring diseases, vectors and drug resistances (e.g. anti-malarial drug resistance), into areas where they are not present. This may result in more severe manifestations of disease or disease at an age when the local population is immune to it.

For a disease to become established in a local population, certain conditions need to be present and favourable (e.g. appropriate vectors and intermediate hosts, environmental conditions etc.).

Examples of diseases whose emergence and spread have been favoured due to HPM disseminating disease, vectors and/or resistance have been noted by Morse (1995), Wilson (1995), Leder and Grayson (1998) and Martens and Hall (2000).

Group A Neisseria meningitidis

Carried by pilgrims to Mecca leading to epidemics of meningococcal meningitis.

Multi-drug resistant Tuberculosis

Brought into western countries by travellers, immigrants and illegal workers (WHO 1998; Sepkowitz 2001).

Human Immunodeficiency virus

Dissemination of the organism via global air travel leading to ongoing secondary spread in developing countries by sexual intercourse with paid sex workers and spread via trade (truck, bus) or tourist routes.

Cholera O139I

Disseminated globally from Asia via travellers. With the El Tor strain, the manifestations may be mild or even asymptomatic allowing travel and dissemination of seemingly healthy populations.

"Airport malaria"

Caused by the introduction of infectious anopheline vectors via an intercontinental flight into a non-endemic country (Zucker 1999).

"Imported malaria"

Rising in many countries, especially the UK, due to travellers returning with malaria. Establishment in new locations generally does not occur though there is a reported instance in Italy where a local vector, *Anopheles labranchiae*, is believed to have bitten a parasitaemic girl who had recently contracted the disease in India (Martens and Hall 2000). This is an example where the hazards of HPM are combined with activities that favour transmission by increasing vector-breeding sites.

Meningococcal disease

Spread by an infected passenger on a plane to a myriad of other passengers with ongoing travel and widespread destinations (MMWR 2001a).

Murine typhus

In travellers returning from tropical countries where it is endemic (Azad and Beard 1998; Parola et al 1999).

Breakdown in Public Health Measures

When local infrastructure is unable to cope with increasing population needs, fertile grounds are laid for the emergence and spread of communicable diseases. HPM or, more specifically, forced HPM can exacerbate these infrastructure demands in a variety of ways. Breakdown in basic sanitation and public health measures leads to favourable conditions for the spread of communicable diseases via contaminated water, increased vector breeding (e.g. rodents, mosquitos) as well as spread of vaccine-preventable diseases.

Mass HPM can create multi-ethnic compositions (e.g. refugee camps) with varying immune status and resistance profiles. Crowded living conditions coupled with inadequate sanitation favours the spread of disease from person-to-person. Sexually transmitted diseases are an excellent example of this. Massive urbanisation, particularly in developing countries, has led to cities with huge populations (mega-cities with populations exceeding 10 million people), which have associated peri-urban slums. These slums have a multi-geographical composition and the poor public health conditions can lead to entrenchment and persistence of certain infections from a variety of original geographical locations, if favourable circumstances and conditions are present.

Some examples by which HPM can cause communicable disease emergence and spread by overwhelming public health measures are via:

- Mass urbanisation
- Refugee movement
- Displaced populations
- Following natural disasters
- Reduction or curtailment of public health measures (e.g. due to any of the above reasons)
- Reduction of vector control methods due to any of the above reasons

Examples of diseases whose emergence and spread have been favoured due to HPM causing breakdown of public health measures are noted by Davis et al (1992), Toole and Waldman (1997), Carballo and Nerukart (2001), MMWR (2001b) and the WHO in a special report (2001).

Cholera and Shigella dysenteriae

Epidemics of these diseases in refugee camps are estimated to have killed approximately 50,000 Rwandan refugees in Zaire in the first month of occupation.

Malaria

Incidence is increasing in urban regions due to massive HPM leading to favourable conditions for vector breeding sites. A lack of vector eradication programs in peri-urban slums has favoured increased human-vector contact.

Measles, diarrhoeal diseases, malaria, acute respiratory tract infections, cholera, hepatitis and meningitis

These diseases are the leading causes of mortality in refugee camps, not just the leading causes of communicable diseases in refugee camps (Davis et al 1992).

Tuberculosis

This disease is a delayed cause of mortality in refugee camps where the crowded living conditions, poor nutritional status combines with inadequate duration and manner of treatment to cause significant health problems.

Alterations in Human Behaviour

Alterations in human behaviour can develop in populations as a result of a number of situations arising from HPM, namely:

- Urbanisation
- Forced migration due to political unrest, armed conflict or natural disasters
- Tourism, especially exposure to paid sex workers
- Refugee and displaced people

These alterations can develop from a breakdown in traditional values and cultural norms. This is especially true in refugee camps and in urban slums. Changing sexual behaviour, drugs and alcohol and intravenous drug use can contribute to an increased incidence of HIV and sexually transmitted diseases.

As has been previously mentioned, the advent of global air travel was a major factor in the dissemination of HIV. One manner is via sexual intercourse with paid sex workers in developing countries. Psychosocial research of tourism has revealed that regression is common in tourism and normal behavioural constraints are sometimes lost in the anonymity of travelling (Leiper 1995). The pyramidal spread of HIV following sexual intercourse with an HIV positive sex worker illustrates the involvement of global travel in the spread of HIV.

Human behaviour in a new region following travel can also increase the risk profile of an individual or population of developing an infectious or communicable disease. This is due to their knowledge of the risk and natural history of the disease being different from that of the local population. Some examples

of how these behaviour patterns and unfamiliarity of the disease increases risks of developing the disease (Wilson 1995).

- Lack of understanding regarding avoidance of mosquitos due to the lack of immune status - unlike the locals who may have varying degrees of immunity to *Malaria* or *Dengue Fever*;
- Lack of, or inappropriate, clothing increasing risk of human-vector contact *Malaria* or *Dengue Fever*;
- Walking barefoot around lakes/dams - increases risk of *Schistosomiasis*;
- Sleeping arrangements - sleeping outside or in unscreened areas *Malaria* or *Dengue Fever*;
- Food preparation - eg eating raw foods or using contaminated water supplies - *Cholera*, *Hepatitis*, *Typhoid*
- Contact with animals vectors, especially rodents - *Hantaviruses*, *Leptospirosis*

Surveillance of the infective consequences of human population movement

It is hoped that utilisation of the previously discussed typology and models of HPM will assist in the anticipation of vector-borne and zoonotic diseases in specific circumstances of HPM. Anticipation would enable measures to be taken to prevent epidemics and check the spread of disease. In the long term, the costs involved in implementing preventative measures would far outweigh those costs involved in the reactive handling of disease outbreaks and the widespread treatment of infections and complications in certain populations. Understanding the risk profile helps in the allocation of resources to counter perceived demands in a more focused and targeted fashion.

Infectious diseases impact statement

McSweegan (1996) follows this theme in his proposal for the use of a pro-active predictive assessment model that he terms the "Infectious Diseases Impact Statement" or the IDIS. He likens this as being analogous to an Environmental Impact Statement (EIS). The IDIS is ideally performed on specified geographical site, usually prior to the development of a large-scale project, such as the building of dams or mines. These types of developments are known to result in significant HPM and possible communicable disease emergence as a consequence. Some examples of large-scale projects precipitating appearance of communicable diseases because of mass HPM are:

- The appearance of Rift Valley Fever following construction of the Aswan Dam in Egypt.
- Epidemics of Malaria and Rift Valley Fever in Senegal following completion of the Diama Dam.
- Increased agriculture along the Argentine pampas leading to frequent haemorrhagic fever outbreaks caused by Junin virus. Similar outbreaks caused by Machupo virus have been noted for the same reason in Bolivia.
- Impoundment of the Volta Lake in Ghana leading to an explosive outbreak of Schistosomiasis in 1968.

McSweegan (1996) proposes that a basic EIS be undertaken, focusing on aspects like:

- Description of human populations in designated areas.
- Current land use patterns.
- Air and water quality.
- Location of wetlands and coastal areas.
- Sources of pollution.

In addition to the above basic environmental features, the specified site is also assessed to determine the infectious disease profile and risk factors:

- Current disease patterns
- Current disease incidence
- Current disease vectors
- Disease profile of the local population and the expected immigrant population
- Immunity profile of the population in question to a range of anticipated diseases and vectors
- Diseases likely to fluctuate in response to the project activity
- Numbers of infected and susceptible hosts
- Existing control measures
- Vectors likely to be affected by the project activities

A combination of the environmental and infectious profiles provides a snapshot view of the conditions in a tightly defined area and possible ways environmental alteration and HPM may change it.

While the timeframe required to undertake the activities required to formulate a IDIS limits its usefulness in acute emergency settings, the concept is a valuable one to be used in planned scenarios of large scale human activity and movement.

Global Surveillance

While it may not be possible to correctly predict and anticipate emergent outbreaks of infectious diseases, the challenge is to have the mechanisms and infrastructure in place to allow control of the situations that can reasonably be expected to occur.

Management of these diseases as a result of HPM requires the basics of public health medicine and management, namely:

- Surveillance
- Response
- Applied research into disease emergence and epidemiology
- Prevention and control
- Adequate public health infrastructure

The discrepancies in the above factors dictate a varying approach to the manifestation and nature of spread of communicable disease via HPM in developing countries as opposed to industrialised ones. In the latter, the measures and concerns are more targeted to the containment of an outbreak or the prevention of entry. In developing countries, the concerns are more fundamental - early detection to prevent mortality (Heymann and Rodier 1998). This, in turn, dictates the nature of public health infrastructure required and the focus with which it is used.

Several review articles have been written on global surveillance of communicable diseases that, while not specifically addressing HPM, outline the necessary steps needed for an adequate system of surveillance (Heymann and Rodier 1998; Grein et al 2000) and the challenges involved in monitoring and surveillance. A thorough discussion of these issues is beyond the scope of this paper, however a brief overview follows.

The basic structure of any surveillance system that will be able to adequately detect and verify an infectious disease outbreak or track its spread consists of the several components which will be briefly outlined below:

- A centralised organization that receives alerts of disease from a range of informal and formal sources.
 - The development of the World Wide Web has lead to several informal sources of disease alerts and outbreaks. One of the more extensive is ProMed. PACNET is another disease alert system,

specifically for the Pacific region. International Health regulations are legally mandated requirements of WHO member countries to report diseases of international importance.

- Assessment by a rapid response disease outbreak verification team.
 - These teams can liaise with local public health services or aid organizations such as Oxfam and MSF for on the ground reports and assistance.
- Determination of the regional +/- international significance of the disease outbreak.
- Dissemination of the outbreak news to a variety of end users via print and electronic means once verified.
- Coordination of epidemic response, ongoing investigations and other public health measures.

Grein et al (2000) report that records from the WHO show that there was a large variance in the time from onset of an outbreak to the outbreak verification team's receipt of the outbreak news. This time ranged from 1 to 215 days and illustrates one of the difficulties in surveillance and response. The more dramatic illnesses like the haemorrhagic fevers were reported earlier than conditions like acute respiratory tract infections and meningococcal disease. The greatest difficulty would appear to be that, throughout the developing world, effective, continuous and accurate surveillance is extremely hard, if not impossible (McSweegan 1996).

These surveillance systems should not focus entirely on human disease, but rather on both human and animal disease, as well as anti-microbial resistance and environmental sequelae of HPM such as changing vectors and water and animal reservoirs (Heymann and Rodier 1998). The ultimate goal of any surveillance system, particularly in a developing world context, is the timely and accurate detection of communicable disease leading to rapid public health intervention in order to minimise the mortality, morbidity and spread of the disease.

The American Society for Microbiology's congressional briefing in 1999 reiterated the global interdependence of communicable diseases in modern times, pointing out that infectious disease agents do not respect geo-political boundaries. It also called for a re-invigoration and a rebuilding of a public health infrastructure, even in the United States, and increased partnerships with domestic and international agencies for surveillance and response.

While it cannot be expected that we will be able to completely eliminate the surprises of emergent pathogens and disease outbreaks, the hope is for anticipation and control of those situations where HPM leads directly to the emergence and spread of diseases (McSweegan 1996).

Conclusion

This article has examined the way that population movement is important in the emergence and spread of communicable diseases by the various ecosystem alterations. Models that seek to predict and explain the possible impacts of HPM on communicable diseases must take into account a variety of factors as well as the geographical pathways travelled to obtain a more holistic overview and therefore a more complete risk profile. Although the risk of emergence and spread of communicable diseases as a result of HPM is complex and is dependent on many biological, social and environmental variables, predictive models can significantly assist our understanding (Wilson 1995).

HPM will continue to unmask new infections and change the characteristics of known infections. The multitude of HPM levels, the global interdependence of communicable disease and the extent of environmental change all combine to ensure that spread and emergence of communicable diseases will be more rapid and of greater magnitude than at any time in human history. The challenge is for the surveillance methods and the public health infrastructure to be equal to the task, whether it be an unexpected outbreak or an anticipated need.

The key to understanding and managing HPM effects is to focus on the integration of information from a variety of spheres and to concentrate on system analysis rather than focusing on pathogens in isolation (Wilson 1995).

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