Geography Compass 1/5 (2007): 1207–1226, 10.1111/j.1749-8198.2007.00060.x

Contagious Cities

S. Harris Ali* and Roger Keil*
Environmental Studies, York University

Abstract

The outbreaks of severe acute respiratory syndrome (SARS) that unfolded at various locations throughout the world represented the first collective threat to public health that was amplified by the processes and structures of our contemporary globalized society – such as, the compression of time and space and increased linkages between various cities of the world. In this article, the global outbreak of SARS in 2003 is used as an empirical referent to discuss the implications of infectious disease spread among and within cities under the conditions of globalization. To capture the uniquely dynamic qualities associated with infectious disease outbreaks under globalizing conditions, we suggest that conventional accounts of the spatial diffusion of pathogens incorporate topological principles that are sensitive to such properties as: fluidity, flows, mobility and networks, that now play a critical role in disease diffusion.

> If the rise of farming was . . . a bonanza for our microbes, the rise of cities was a greater one, as still more densely packed human populations festered under even worse sanitation conditions. (Diamond 1999, 205)

> The explosive increase of world travel by Americans, and in immigration to the United States, is turning us into another melting pot – this time, of microbes that we previously dismissed as just causing exotic diseases in far-off countries. (Diamond 1999, 206)

Introduction

Contagion involves the transmission of infectious disease agents. It may occur through person-to-person contact or indirect contact with insect or animal vectors and contaminated materials such as blankets, money, water or food. Urban environments in particular have historically been associated with the spread of contagion. Several reasons account for this. First, the high density of interacting individuals in the city provides a host population large enough to support the continuous circulation of pathogens. Prior to the generalization of urbanization since the industrial period, pathogens – most of which originate from animal reservoirs – were limited to infecting only those in rural areas and upon killing the relatively fewer human hosts accessible to them, the pathogen population itself could not sustain itself (McMichael 2001). With urbanization, the circumstances changed to better enable the survival of pathogens, not only in terms of providing a sufficient number of human hosts, but also by providing certain unhygienic conditions that created a favourable biophysical environment for both pathogens and disease vectors. Third, because cities act as hubs in economic, transportation and social networks, they could also serve as points of concentration for pathogens arriving through the various media via their respective networks (e.g. food, water, air, waste distribution networks), thus increasing the potential for contagion (Ali and Keil 2006).

Central to the phenomenon of the 'contagious city' and a key area of research for medical geographers has been the spatial diffusion of infectious disease. Two dimensions are involved here – one external and one internal to the city. Thus, when speaking of 'contagious cities', we are actually referring to contagion in two senses – the spread of disease among individuals *between* cities and *within* cities. The infectious disease must first be introduced into the city from an external place (such as another city or an adjoining rural area) and once introduced the disease may spread within the city itself. To account for the spatial diffusion of disease in these two senses, medical geographers have developed mathematical models that quantitatively define the mechanisms involved in the movement of pathogens through time. One important mechanism to account for the spread of infectious disease between cities is known as relocation – the introduction of a pathogen to a new location that is not part of the interactions from which it originated. Relocation often involves leaps over great distances and intervening populations (Meade and Earickson 2000, 265). A common relocation dynamic has been found to be hierarchical diffusion, which describes how a pathogen can spread through a series of cities as a function of their relative size. As described by this mechanism, a pathogen must first find its way to a large city at or near the top of urban hierarchy. From here, it will cascade down to smaller cities lower in hierarchy as people travel from larger cities to smaller cities. Gould (1993), for example, has demonstrated that the rapid spread of HIV/AIDS in the USA from 1984–1990 could be described by hierarchical diffusion. In terms of the spread of an infectious disease within a city, the mechanism that is commonly used to describe this phenomenon is contact diffusion where individuals must be in proximity to each other so as to facilitate the travel of the pathogen among a group of human hosts. As alluded to above, because most epidemic diseases are 'crowd diseases', they depend on the clustering of the human hosts into densities that are able to sustain an infection chain through contact diffusion (Haggett 2000).

It is our contention that, under the contemporary social and material conditions of globalization, models based wholly on descriptions of hierarchical and contact diffusion may be inadequate unless they take into account the highly mobile and dynamic nature of the relationships between and within cities. This includes the travel and transport of humans and non-humans (commodities, food, etc.) between and within urban areas. To move in this direction, we suggest the adoption of analyses that are informed by a more topological and network based approach. It is further argued that such an orientation has the potential to take into account much better the social and political conditions that influence the spatial diffusion of disease and open the door to a more comprehensive and penetrating analysis of disease outbreaks. We will illustrate the need for such an approach by considering the global outbreaks of severe acute respiratory syndrome (SARS).

The SARS Outbreak

The mode of transmission of SARS is thought to be through the travel of respiratory droplets from person to person, although environmental transmission through a faulty sewage system in an apartment complex in Hong Kong has also been documented (National Advisory Committee on SARS and Public Health 2003). Commentators have noted that the response to the global outbreak of SARS has provided a valuable learning opportunity to plan for other respiratory-borne disease epidemics, such as the next big flu epidemic, or a future epidemic of multidrug resistant tuberculosis (Davis 2005; Levy and Fischetti 2003). The value of this opportunity is especially appreciated if one considers that although SARS epidemic of 2003 was different from past epidemics, it is exactly these differences that may have relevance for the nature of future epidemics. Let us consider how this was so. First, what is notable was the unprecedented speed at which SARS spread – largely attributable to jet travel. Within a one-week period, SARS was found within some of the major cities of the world, which brings us to the next difference, namely, the mode of transmission. As we have discussed elsewhere (Ali and Keil 2006, forthcoming), what distinguished SARS from other outbreaks was its spread through a network comprised of some of the most influential cities of the world (i.e. the global cities network). Third, the technical and political response to SARS was unique. For example, never before had the world's scientific might collaborated together (as facilitated through the Internet) on one phenomenon with such intensity – resulting in the outcomes of identifying and genetically characterizing a new viral agent in the unprecedented period of several weeks (Heymann et al. 2005). And, at the political level, the World Health Organization (WHO) took the unprecedented action of issuing travel advisories against certain SARS-infected cities (to be discussed in more detail later). The enhanced speed of viral travel, the implication of the global cities network, and the changing role of the WHO and the advent of the Internet will surely be of significance in future outbreaks.

The coronavirus responsible for SARS (S-CoV) is thought to have originated in the palm civet cat reservoir in southern China (Guan et al. 2003). The civet cat is sold for human consumption and the first human cases of SARS were identified in November 2002, as workers and food handlers in the live animal markets (also referred to as wet markets) of the southern Chinese province of Guangdong became ill with a mysterious disease then classified as 'atypical pneumonia'. In February 2003, an old physician who treated patients with this disease in this area travelled to Hong Kong where he stayed at the Metropole Hotel to attend a relative's wedding. This index case was later classified as a 'superspreader' (Centers for Disease Control and Prevention 2003) – an individual who, unexplainably, exhibits enhanced infectivity (although it is postulated that superspreaders may have higher viral loads or produce more respiratory secretions). From this initial case, 11 hotel guests became infected. Among these guests were those who continued their travels within Hong Kong and to other major cities such as Toronto, Singapore and Hanoi where local outbreaks resulted. By late March 2003, there were 1320 confirmed cases of SARS with 50 deaths throughout the world (Murray 2006, 20).

One of those infected in the Metropole Hotel was an old mother who transmitted the virus to her son on her arrival home in Toronto. The mother tragically succumbed to the disease at home while the son died in a local hospital. In a short period of time after exposure to the ailing son, two patients sharing a hospital room with this primary case became infected and through exposure to these two patients alone, a total of 38 others became ill – including family members, paramedics, emergency department staff, housekeepers, visitors and physicians (Low 2004). A second transmission chain involved a Toronto charismatic religious group whose parish membership largely consisted of individuals of Filipino descent. Many parishioners attended a funeral of an old member who had contacted SARS from the index hospital (at the time it was not yet known that the deceased had died from SARS). Once the possibility of exposure to SARS became known, 500 members of this religious community were ordered into quarantine by Toronto Public Health officials, but one person who attended the funeral visitation (a 44-year-old man) had already passed away from the disease (Basrur et al. 2004). The possibility for a third transmission chain was also identified. In late March 2003, a Toronto nurse's aid contracted SARS through contact with her roommate's mother (for whom she was caring). The mother had become infected from a visit to a Toronto area family clinic (Scrivener 2003). In early April, unaware of the seriousness of her illness, the Toronto nurse's aid travelled to Manila to tend to her father who was suffering from colon cancer. The next day after arrival, she attended a wedding with several hundred guests and for several days subsequent she travelled around the Philippines (while coping with her worsening illness) but passed away from the disease soon thereafter. Similar intracity transmission dynamics unfolded in other affected areas, notably, in some of the 'busiest and most dynamic cities in the world' (Abraham 2004; see also Ali 2006).

The international response to SARS was coordinated by the WHO. The WHO became actively involved shortly after one of its physicians based in Hanoi died from the disease in late February 2003 upon treating an infected guest from the Metropole Hotel. At this point, the WHO activated its Global Outbreak and Response Network (GOARN) – a response network of 100 national government and scientific institutions with expertise in infectious disease. SARS was the first *international* outbreak identified and responded to by GOARN (Heymann et al. 2005) and the threat represented a new type of challenge because it was a non-focal, multicountry outbreak of an unknown disease threat (National Advisory Committee on SARS and Public Health 2003). GOARN members were quickly mobilized by forming teams of experts that worked collaboratively with local operational teams in SARS-affected areas (WHO 2003a). The institutional and field teams of experts would meet together on a daily basis to review progress, compare experiences and plan further action through video or teleconferences. In parallel with the activities of GOARN to track the spread of the disease, the WHO also coordinated clinical and laboratory efforts at the international level aimed at (i) developing a universal case definition for the illness that could be used by clinicians around the world to definitively identify SARS cases; (ii) identifying the particular virus that was causing the disease; and once identified, (iii) developing clinical tests to identify the presence of the virus in suspected cases; and (iv) specifying the genetic code of the virus in order to begin work towards the development of a vaccine. Such efforts were largely successful. The rapid identification of the S-CoV as the causative agent and the subsequent delineation of its genetic code – all within a one-month period – was hailed by the WHO as the hallmark of global international scientific collaboration. Such an effective technical response highlighted the importance of international informational networks; especially the Internet in contemporary global infectious disease response (Heymann et al. 2005). The international SARS response reveals a positive aspect of globalization; thus, although the forces of globalization may have facilitated the diffusion of infectious disease in certain ways, they may also increased the potential for an effective and coordinated international response in other ways.

Observers have noted the SARS outbreaks were successfully contained through the use of traditional public health methods of contact tracing, surveillance and quarantine (National Advisory Committee on SARS and Public Health 2003, 35). The success in containing the community-wide spread of SARS, however, probably also involved the nature of this particular disease itself. Much of the spread of SARS was nosocomial, that is, it was limited to the hospital setting; consequently, those primarily affected were patients and healthcare workers (and their families). In the case of SARS, nosocomial transmission was predicated upon the fact that infected persons were most contagious at the point at which they were the most ill. In turn, such individuals would more likely enter the hospital setting to receive care, thus increasing the potential for spread within the healthcare setting (National Advisory Committee on SARS and Public Health 2003). Nevertheless, the threat of community spread persisted as healthcare workers, family members and visitors would, as expected, return to the community after their hospital shift or patient visit. As such, hospitals, as we will discuss in more detail later, played a key contributing role in making the city 'contagious'.

Globalization and Infectious Disease

The phenomenon of globalization has been conceptualized in various ways, but at the root of most of these is the phenomenon of time-space compression in which previously distant locations around the world are linked together much more closely due primarily to dramatically shortened communication and travel times (Giddens 1990; Harvey 1989). In this context, Held et al. (2002) define globalization as 'those spatio-temporal processes of change which underpin a transformation in the organization of human affairs by linking together and expanding human activity across regions and continents' (p. 61). Time-space compression has resulted in certain developments that are integral to the nature of globalization. First, there has been an increase in the *extensivity* of global networks in which the reach of networks of social activity and power has been expanded. Second, the *intensity* of global interconnectedness has increased, as evidenced by the growth in the sheer volume and magnitude of interconnected flows and interactions of various global flows, such as those involved in trade, investment, finance, migration, culture and so on. For example, the extensivity and intensity of contemporary global interconnectedness is seen quite explicitly in the case of the international SARS response, where an extensive number of experts from around the world were quickly mobilized and connected to each other through the coordination of the WHO. Third, the *impact propensity* of global interconnectedness has increased in such a way that the impact of distant events is magnified while concurrently, local events may have global consequences. Thus, with respect to the SARS situation, one observer notes (somewhat sardonically) that,

> Globalization means that if someone in China sneezes, someone in Toronto may one day catch a cold. Or something worse – if, in Guangdong province, 80 million people live cheek by jowl with chickens, pigs and ducks, so, in effect, do we all. Global village indeed. (Editorial Comment, *The Globe and Mail*, 29 March 2003)

Finally, the *velocity* of global flows of interactions and processes has speeded up with the development of worldwide systems of transport and communication thereby supporting the increased diffusion speed of ideas, goods, information, capital and people. This is particularly significant in terms of the spatial diffusion of disease. Today, the increased speed (and volume) of jet travel has meant that the spread of infectious disease is a much more pressing problem than in the past because the air travel time between any two major cities of the world is less than the incubation period of many pathogen-based diseases. Consequently, infected air passengers may be asymptomatic on arrival at their destinations. Furthermore, infectious disease can spread among the passengers themselves during air travel. For example, Wilder-Smith et al. (2003) note that one traveller with influenza onboard a plane that was grounded for 3 hr infected 72% of all passengers. In the case of SARS, 6.5 passengers per million, travelled as symptomatic probable cases departing from locations with local transmission of SARS in March 2003 and there were 40 flights on which one or more probable SARS cases travelled while symptomatic during the outbreak period of February to May 2003 (WHO 2003b). SARS transmission occurred from such individuals to other passenger and crew members on five international flights. It should be noted that, although the risk of in-flight transmission of SARS may be lower than the case of influenza, the risk is increased if the person infected is a 'superspreader'.

Another dimension in the study of globalization involves the identification and analysis of the economic, political and cultural linkages that serve as the foundation of globalization and the study of these linkages has important implications for the study of infectious disease flow. Let us illustrate this through the case of SARS. After its initial emergence in southern China, SARS spread to particular major cities throughout the world, namely those known as 'global cities' (Ali and Keil 2006) – that is, urban centres that serve as the command and control posts of the world economy (for a review of the global cities literature, see Brenner and Keil 2006). It has been found that such cities form the backbone of the global economy and are interconnected in various ways through different types of material and information flows (Castells 1996, 2000), such as labour market and investment cycles (Scott 2000), knowledge and policy transfers, cultural exchange (Flusty 2003), airline passenger flow (Smith and Timberlake 2002) and the transnational movement of people (Smith 2001). In particular, in studying these various connections and flows, a discernable pattern can be identified in which certain cities of the world serve as nodes in an interconnected network, referred to as the 'global cities network'. Notably, until the SARS outbreaks, what was not so clear was that the global cities network could also serve as a conduit for pathogen transmission as the disease spread from the global city of Hong Kong to other such cities such as Singapore, Toronto and Hanoi. The question then arises, what is it about the global city and the network in which it is embedded, that facilitated the spread of disease in this manner? To a certain extent, the answer lies in chance occurrences. That is, the fact that a superspreader entered a particular hotel in one global city and infected other international travellers who by chance became superspreaders themselves. The role of chance and contingency in the viral diffusion of SARS may be thought of as an inherent and typical quality of the nature of contemporary globalization processes in general and the global city in particular and it is towards such issues we now turn.

Globalized Flow, Mobility and Flux: Implications for the Diffusion of Infectious Disease

From our brief review of the diffusion of the SARS coronavirus, one cannot help but note the dynamic nature of the transmission chain involved – from the rural/urban interfaces of the live animal markets in southern China, to the major global city of Hong Kong, and from there to other global cities such as Toronto, Singapore and Hanoi, and from such cities such as Toronto, to other cities such as Manila. The challenge in tracking, and thereafter preventing, the spread of an infectious disease such as SARS is to take into account this type of dynamism. As alluded to above, such dynamism may be thought of as a function of globalization processes and the networks that comprise and facilitate these processes. We contend that in order to capture the inherent dynamism involved in the spatial and temporal diffusion of infectious disease in contemporary times requires new ways to understand the city – including a renewed consideration of connectivity among cities and between cities and rural areas. To capture these dynamic qualities, we consider notions such as flow, flux, mobility and the fluid network to reconceptualize the relationships between cities and infectious disease under the conditions of globalization.

The concepts of network and flow cannot be understood independently of each other. This is because the nodes that constitute a network must be connected with each other in some way. One way to consider these interconnections is through the notion of flows. As mentioned above, a global city network may be discerned on the basis of various types of flows (information, capital, goods and people) wherein global cities serve as the nodes connected through these flows. In fact, as van Wagner (forthcoming) observes, an essential aspect of what defines a particular city as 'global' is its connection to the network of international travel and trade between 'global cities' and the more critical the flows of people and goods are for the maintenance of the economic network, the more 'global' the city is. In reference to communicable diseases, however, the movement of people is probably the most critical flow type because it is on this basis that microbes are able to traverse the world via the global city network.

Callon and Law (2004) point out that within any network, the more a node is connected to others, the more influential it will likely be. That is, because a particular node having a higher number of contacts will potentially play a role of greater significance in the network. As such, size (or impact potential) should not be considered a matter of scale, but of connection (within the context of network functioning). In the case of the nodal connections involving the flow of people, the nature of the global city as a node within a network of contacts must be considered in terms of its potential importance for the diffusion of disease. For example, in the case of SARS, Hong Kong, as one of the larger global cities (as defined in terms of the density of connections), was host to travellers from many parts of the world. Similarly, Toronto, as one of the most multicultural cities in the world, is host to a large number of diaspora communities, whose members will likely have relatives in other global cities. Thus, MacPherson and Gushulak (2001) note that there has been a changing demography of mobile populations that is in part due to increasing ability to travel, greater access to transportation, reduced travel times, and the sheer volume of humanity on the move and this all has implications for infectious disease flow. The qualitative and quantitative nature of the diasporic connections in the global city network, as well as minority communities within a particular global city, has very important implications not only for the spread of infectious disease but the reaction to it as well. For example, in the case of the former, Urry (2004, 32) notes that the proliferation of diaspora communities in the modern age has extended the range, extent and significance of travel as '[d]ispersed people, once separated from homelands by vast oceans and political barriers, increasingly find themselves in border relations with the old country thanks to a to-and-fro made possible by modern technologies of transport, communication, and labour migration.' For Urry, what is particularly notable with this type of globalization process is the increasing importance of 'occasioned encounters' where people travel to be copresent with others for specific periods at specific places. Occasioned encounters as a type of connection (and flow) is particularly important for the spread of disease, as illustrated by the case of the infected Torontonian who travelled to Manila to visit her ailing father and attend a relative's wedding, or the case of the infected physician from southern China who travelled to Hong Kong to attend his nephew's wedding.

It should also be noted that the diasporic quality of global cities also has implications for the social and political reaction to the spread of infectious disease. It has been documented, how, for example, members of the Chinese-Canadian community in Toronto experienced a degree of stigmatization and scapegoating during the outbreak (Leung and Guan 2004). Furthermore, such negative reactions based on the association of infectious disease with a racialized group have deeper implications for the understanding of the postcolonial realities of diasporic groups within an age of globalization. In this connection, King (2002) notes that the earlier efforts of colonizers at territorializing disease threats, by limiting their containment efforts to the colonized lands, have been replaced by a postcolonial perspective based on managing disease spread through de-territorialized networks in which the surveillance of particular groups can be undertaken through the collection of relevant data. Elsewhere we argue that such postcolonial methods of surveillance and social control have recently intensified and further conflated the association of race/ ethnicity with disease because of the development of a sense hypervigilance and a paradigm of suspicion after the terrorist attacks of 9/11 – all of which may have furthered the racialization of SARS as a 'Chinese disease' (for further details, see Ali 2006; Keil and Ali 2006; Keil and Ali forthcoming).

The dynamic nature of flows between cities naturally leads to the need to consider the role of mobility in defining the nature of the relations between cities. It is important to consider the extent of international mobility (between global cities in particular) because a disease may be present in non-epidemic form for many years until environmental, structural or behaviour changes allow for its spread into epidemic form (Ali 2004). We have already discussed this in terms of the significance of air travel and the implications that has had for the spread of SARS, but what needs to be emphasized here is that this form of travel has made the connections between cities much more fluid than the connections between cities of the past. Thus, van Wagner (forthcoming) notes that the idea of a 'fluid network' is one of the aspects of contemporary globalization that sets it apart from former stages of international travel, trade and colonization. The reconceptualization of the global cities network away from a static model towards a more fluid model also has implications for the conceptualization of the global city itself. This is because the global city and the global city networks are co-constituents. That is, if the network if fluid, so too will be the nodes that comprise the network. In this light, global cities may be thought of as *modulators* of flows. Another way of conceptualizing the city in these terms is to understand it in terms of its 'ability to enroll and mobilize others to perform in "their" network' (Smith 2003, 576). What should be noted, however, is that such network enrolment and mobilization processes may have unintended consequences due to the role of chance developments in the network. This is seen, for example, by the unpredictable but uniquely defined movement of unsuspecting superspreaders through the global city networks.

Cities may also be thought of as points of convergence of many different types of flows from around the world, including for example, flows of ideas, people, culture, commodities, and so on (as well as the points from which flows originate to traverse other parts of the world, including, most notably, other cities). The impacts of such flows on the economic and social life of the city (and vice versa) are therefore understandably dynamic and fluid. The logical extension of this is, if these flows that constitute the city are fluid by nature, then so too will be the city, particularly in the context of the dialectical relationships between the local and the global. Flows are global, but have local effects and vice versa. Thus, Amin (2002) notes that the reconfiguration of the spatiality of social relations according to the local–global dialectic is a central aspect of contemporary globalization and a central determinant of what goes on in places (localities, cities, regions); how places coalesce or not as entities; and how social relations in place are constructed. This perspective of the city is perhaps best conceptualized through the adoption of a more fluid model of the city; one in which cities are reconceptulized as 'as unbounded and polyrhythmic spaces, no longer understood in terms of fixed locations in abstract space, but rather in terms of a continuously shifting skein of networks, with its own spatiality and temporality' (Braun forthcoming). The unbounded quality of the global city refers to the 'porousness' of the city border, whereby the various flows of people, information, images, goods, capital, and so on, enter and exit the city with little hindrance. At the same time, the polyrhythmic quality of the city is an emergent phenomenon that is founded on the rhythms of the 'space-times' of the multiple networks that compose the city itself (Ali forthcoming). For example, the outbreak of SARS in Toronto demonstrated how the city and the outbreak was a contingent effect of a series of networks and flows, each with its own defining rhythm and location of origin, including the rhythms, for example, of the live animal markets in southern China, the travels of a medical professional, hotels in Hong Kong, the travel patterns of guests in a particular hotel, transcontinental air flights, the occasioned encounters of those in various diasporic communities, hospitals and even larger socio-political forces such as the restructuring of public health in the province (on this issue, see Ali and Keil forthcoming; Salehi and Ali 2006; Sanford and Ali 2005). It is in such a context the Braun (forthcoming) notes that 'Different people, new products and strange pathogens are continuously entering into novel configurations.'

Fluidity, Flow and Outbreak Response

Many of the problems faced in the various responses to SARS at different levels have to do with the inability to recognize and deal with the fluid, unbounded and polyrthymic qualities of the contemporary global city. This is most evident in considering the role of city hospitals during the outbreak response in dealing with the 'borderless challenges' (Fidler 2004) posed by infectious disease in an age of globalization.

Although screening and surveillance measures such as thermal imaging and diagnosis by screening nurses were adopted at the major airports in Canada, one Health Canada official noted that they were completely ineffective because all persons who came to this country with SARS were asymptomatic upon arrival (St. John 2003). Upon becoming ill, all such individuals sought care in the hospital emergency room and not the physician's office. Hospitals therefore became sources of SARS transmission and a potential danger to health as healthcare workers became infected. Thus, Affonso et al. (2004) notes that, 'SARS has turned the previously solid boundary between medical and communal spaces into a permeable and fluid one. SARS unified the spaces of hospital and community in a highly unexpected manner.' In this context, traditional geo-political borders were no longer found to provide 'protection', while the new 'border' for infectious disease was discovered to be the doors of the hospital and not the airport (St. John 2003). In this sense, the old concept of quarantine has become outdated.

The role of city hospitals as conduits for flow of humans and viruses was critical for the diffusion of the SARS coronavirus within the global city. For example, in Singapore, within 8 weeks, staff and patients spread the virus to five city hospitals and two nursing centres in Singapore (Nikiforuk 2006, 230), while in Taiwan, an infected individual misdiagnosed in a hospital subsequently visited numerous other hospitals and clinics spreading the infection widely (Murray 2006, 20). In Toronto, the flow of the virus may have been enhanced as a consequence of certain policies that impacted on the livelihood of nurses. Specifically, due to neoliberal policies that emphasized a reduction in government funding of salaries, many nurses were forced to work on a part-time (or 'casual') basis. Such circumstances increased the potential for interhospital spread of the SARS coronavirus, as nurses would work part-time at several hospitals to earn the equivalent of a full-time wage. Perhaps due to the directive that nurses only work at one site (Burcher 2003) during the SARS outbreak, only one case of interinstitutional transmission was documented (National Advisory Committee on SARS and Public Health 2003), but the situation could have been much worse. These experiences highlight the fact that hospitals, particularly those in urban centres, must be taken into account the impacts of globalization in their day-to-day operations because as Nikiforuk (2006) notes, 'SARS found everything in a hospital that a globally ambitious invader needs: lots of traffic, highly mobile staff, unclean quarters, massive overcrowding, and plenty of immunocompromised individuals' (p. 228). For this reason, St. John (2003) recommends that in the global era, city hospitals in particular must build their capacities for the rapid detection, diagnosis and response capabilities for infectious disease, including an increased importance on obtaining travel histories in the emergency room. Furthermore, these experiences demonstrate how flows (in this case the flow of nurses between city hospitals) may be influenced by political, economic and cultural forces, such as those associated with neoliberalism.

The consequences of the fluidity of human flows in the global era can also be understood within the context of the international response to

SARS. David Fidler (2003) contends that the SARS outbreak may be thought of as the first post-Westphalian epidemic. Established in 1648, the Peace Treaty of Westphalia led to a truce among warring European states and was formulated on the basis of notions such as the sovereignty of the individual nation-state to rule over its people, and the principle of non-intervention by other nation-states into the domestic affairs of a particular nation-state. Since then, the Westphalian governance framework has defined the nature of international public health interventions for over three centuries in various ways; most notably, in enabling individual nation-state powers to treat public health threats, such as disease outbreaks, as domestic affairs. According to Fidler (2003), the principle of non-intervention was violated in dealing with the SARS outbreak in several ways; the most prominent example being the imposition of international travel advisories by the World Health Organization (WHO) on various SARS-affected areas such as Toronto, China's Guangdong and Shanxi provinces, as well as the cities of Beijing and Hong Kong. This advisory that recommended the global citizenry not travel to the SARS-affected areas would remain in place until the state power in those affected areas adopted certain public health directives issued by the WHO (including the use of certain screening technologies, such as thermal scanners at airports and conveyance of detailed epidemiological reporting of SARS cases to the WHO). Furthermore, these warnings represented 'the toughest travel advisories in its 55-year history' (Gostin et al. 2003). In light of the unprecedented actions taken by the WHO in response to SARS, it was evident that public health was no longer the sole responsibility or exclusive jurisdiction of the sovereign state, thus resulting in what could be characterized as a post-Westphalian socio-political condition. As such, the WHO response to SARS could be thought of as a somewhat necessary adaptive measure to the enhanced conditions of contagion under globalizing conditions, particularly the impact propensity of global interconnectedness in which the impact of a local outbreak on a distant location may be magnified and the intensity of global interconnections where the patterns of interactions and flows that facilitate pathogen transfer transcend nation-state (and city) boundaries.

Towards a Network and Topological Understanding of Infectious Disease Spread

The worldwide outbreaks of SARS dramatically illustrates that with globalization, what at first sight appears as localized events, can have unexpected, disproportionate and emergent effects that are often distant in time and space from when and where they first originated. Such a development takes us back to the notion of flows, because it is essentially flows and the networks in which they are embedded, that enable the 'action at distance' and the connectedness that are the defining characteristics of such globalizing effects. In this light, the ostensible role of chance in the emergent phenomenon of a disease outbreak is related to the inherent uncertainty associated with the movement of flows. This is because the flow of pathogens across regions occurs in a faster and unpredictable manner in which there appears to be no clear point of arrival or departure. Moreover, as complexity theory and chaos theory assert, once a certain level of complexity is reached due to the increasing number and types of interconnections, unanticipated, non-linear phenomena may emerge (Urry 2000, 2005), thus further contributing to the fluidity and unpredictability of events such as disease outbreaks. Epidemiological and spatial diffusion modelling, however, attempt to deal with such unpredictability and uncertainty in an effort to gain some sense of order on which basis predictions of disease spread can be made. Attempts to gain some perspective on pathogen movement in an unbounded, polyrhythmic world is challenging to say the least, but they are in fact similar to efforts in other sectors to chart the movement of other objects under comparable conditions of globalization. For example, the track-and-trace approach used by courier services such as Federal Express (Thrift 2004) to chart the movement of packages across the globe are based on similar approaches to those used by epidemiological modellers on the basis of public health surveillance data obtained through contact tracing.

Conventional disease diffusion perspectives, such as those based on hierarchical diffusion models, may resort to the use of networks in their respective analyses. However, such approaches tend to conceptualize networks in a rather Cartesian way in which the network fixes things in particular space-times that imply predictable and linear trajectories. A noble effort, but in light of the remarks made above concerning the fluid, polyrhythmic, uncertain and emergent qualities of disease outbreaks, an alternative model informed by these other types of considerations may be needed for a more accurate account of a disease outbreak under contemporary circumstances. In particular, such an alternative model would be cognizant of the idea that proximity should not be thought of necessarily in terms of physical distance but in terms of connection (Thrift 1999). Progress in this direction may perhaps be made by incorporating perspectives from the mathematical field of topology into existing disease diffusion models. Topology is a branch of mathematics that analyses space in terms of convergence, the degree of connectedness of points in space and continuity. In essence, topology conceptualizes space in terms of nearness and rifts that contrasts to the conventional approaches of metrical geometry that deals with stable and well-defined distances. Thus, Smith (2003) notes that, 'near and far become less meaningful when a metric of theory of space and time is rejected in favour of a topological theory where space-time is viewed as folded, crumpled and multi-dimensional.' For example, if two points are drawn a piece of paper, the distance between the points can be calculated using metrical geometry. However, let us say that this piece of paper is randomly and repeatedly crumbled up, the question of the distance between the two points at any given time (which keeps changing because of the repeated action of crumbling up the paper) than becomes a topological question. This latter approach therefore is better suited to modelling the movement of pathogens under the ever-changing and dynamic conditions of globalization in which a given space, such as a city, is always changing because of the continual flux of flows in and out of it and the ever-changing fluid network in which the city is embedded. As such, to account for such dynamism, the incorporation of topological principles into models of disease diffusion may better serve to capture the spatio-temporal reality of our day. In this light, one subspecialty within topology may have particular relevance to the study of disease spread, namely, network topology, a field of research that emphasizes the physical arrangements of the nodes of a given network. Recently, researchers have started to explore the potential for such approaches in the spread of infectious disease.

The use of a networked topology approach to disease has only become possible within the last two decades – largely, due to the advent of more and more powerful computers, which now makes it possible to deal with the extremely large data sets needed to characterize the topology of large networks. For example, analysis has already begun on studying the connectivity of systems such as the electric power grid of a nation, the citation patterns of scientific publications and the users of the World Wide Web (Barabási and Albert 1999). Models based on such analyses have been fine-tuned with time, as certain assumptions are corrected so as to better simulate the reality of networked phenomena. In relation to the spread of disease, the most promising of these evolving models are the so-called 'small-world' approaches (Watts and Strogatz 1998) – named after the six degrees of separation conceptualization in which it is argued that any two people in the world are connected to each either other through, at the most, five intermediaries. Topological network analyses based on the small-world model consider how diseases spread in localized clusters of individuals in close contact with each other, as well as through the connection of individuals separated by vast distances (Shirley and Rushton 2005). In other words, these approaches simulate a mode of disease transmission in which the contact structure of individuals is based on a both of local and global linkages of personal contacts (Dybiec et al. 2005). In theory, therefore, such approaches would be able to take into consideration how a disease spreading in one particular global city (i.e. contacts based on the local personal links within a city) would be able to spread to another very remote global city within the global city networks (i.e. city–city linkages). The advantage of this small-world approach to previous approaches is that it does not assume that every individual has an equal chance of spreading the disease to each other, rather, it considers the possibility of preferential attachment (Barabási and Albert 1999), such as those interactions between family members or those involving healthcare workers and patients (Meyers et al. 2005).

In terms of our discussion here, the networked topological approaches are an improvement to earlier hierarchical diffusions models because they represent a way in which the fluid, unbounded and polyrhythmic qualities of cities may be taken into account. In particular, knowledge obtained through these models will be more in touch with the reality of our globalized and urbanized world. This in turn should result in more effective guidelines with respect to breaking the chain of transmission (through isolation and quarantine) and controlling the outbreaks of an infectious disease under the particularly dynamic circumstances and conditions of our contemporary existence. At the same time, it should be borne in mind that because these disease-tracking models, and the guidelines developed thereof, involve the collection of large amounts of data of a personal nature, such as health, familial/social network and travel information, there is a need to ensure that such data are not used for other less noble purposes, such as that of unwarranted and unethical urban surveillance, racial profiling or prosecution of marginalized groups (see Ali et al. 2006) – an especially important consideration in a post-9/11 era as alluded to above.

Conclusion

The institutionalization of public health was shaped by earlier, limited and often crisis-focused responses to changing disease threats. For example, Garrett (2000) notes that during the turn of the 20th century, New York City, as a global trading post of its day, had to contend with a succession of disease outbreaks as microbes converged on the city through the flow of cargo and people from around the globe, and in response, the city established the world's first public health infrastructure. Today, major metropolitan areas must again contend with a changing disease threat, specifically, a threat based on the intensified and dynamic qualities of human and pathogen flow. Indeed, as van Wagner (forthcoming) observes, one of the most important lessons of SARS is that the prized status as a 'global city', may facilitate the movement of microbes and disease as much as that of capital, commodities or people. Furthermore, such movement may be influenced by social and political forces, such as neoliberalism in the case of the viral flow in Toronto, or a post-Westphalian intrusion on sovereignty in the case of the international flow of the virus and may even draw out negative social response such as the stigmatization and racialization of those affected.

Cities, and global cities in particular, are points of convergence through which diverse and numerous global flows move. In this context, that a global city should not be conceptualized as a static and bounded entity, but as an unbounded, fluid and emergent outcome. This development is essentially an effect of globalization and as Smith (2003) notes, globalization defies both geographical borders and temporal frames such that global cities must be understood in non-scalar and non-linear terms and this has special implications for the study of contagion. This is because the manner in which pathogens move throughout the world today has to do with nature of the networks and how they are constituted. Networks and flows are relational phenomena and each cannot exist independent of the other, thus to study diffusion of pathogens requires a consideration of the nodes and networks in which microbial flows take place. To take such consideration into account, we suggest the need for an alternative and less structural perspective of contagion, one in which topological concepts and approaches are central.

Short Biographies

S. Harris Ali is an Associate Professor at the Faculty of Environmental Studies at York University, Toronto, Ontario, Canada. His research interests involve the study of environmental health issues and the sociology of disasters and risk from an interdisciplinary perspective. He has published on toxic contamination events and disease outbreaks in such journals as: *Social Problems*, *Social Science and Medicine*; *Canadian Review of Sociology and Anthropology*; and *Journal of Canadian Public Policy*.

Roger Keil is the Director of the City Institute at York University and Professor at the Faculty of Environmental Studies at York University. Among his publications are *Los Angeles: Urbanization, Globalization and Social Struggles* (Chichester: John Wiley, 1998); *Nature and the City: Making Environmental Policy in Toronto and Los Angeles* (with Gene Desfor) (Tucson: University of Arizona Press, Nature and Society Series, 2004); (ed. with N. Brenner) *The Global Cities Reader* (London and New York: Routledge, 2006). Keil is the co-editor of the *International Journal of Urban and Regional Research* and a member of the *International Network for Urban Research and Action*.

Acknowledgements

This research was supported by a Social Science and Humanities Research Council of Canada Standard Research Grant. The authors would like to thank the anonymous reviewers and the editor for their helpful comments.

Note

* Correspondence address: S. Harris Ali and Roger Keil, Environmental Studies, York University, Environmental Studies, 4700 Keele Street, Toronto, Ontario, Canada M3J 1P3. E-mail: hali@yorku.ca; rkeil@yorku.ca.

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