Time for an ecosystem approach to public health? Lessons from two infectious disease outbreaks in Canada

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Abstract

Ecosystem approaches recognize the complexity of many contemporary public health challenges and offer an alternative for dealing with problems that have proven intractable and unresponsive to conventional public health strategies. Infectious disease outbreaks are among the most dramatic aspects of systems failure, and the Canadian cases of SARS (Severe Acute Respiratory Syndrome) in Toronto, and the *E. coli* outbreak in Walkerton, serve as useful illustrative examples. This paper examines some of the limitations of current public health approaches, the fundamental tenets of an alternative, transdisciplinary ecosystem approach, and changes necessary for implementation, including those in philosophical approach, communications and education and, finally, institutions and governance.

Keywords: *Ecosystem, public health, infectious disease, transdisciplinary, governance*

Introduction: The symptoms

The 20th century saw major improvements in health and life expectancy. Nevertheless, many vectorborne, waterborne, foodborne, and airborne diseases, as well as a range of noninfectious diseases, are emergent, re-emergent or resurgent. (McMichael 2001, Millennium Assessment Report 2005). Concomitantly, ongoing chronic neglect of public health infrastructure in favour of acute health care, increasing economic disparities within and between countries, and large-scale ecosystem disruptions, are placing global health increasingly at risk.

Public health focuses on interventions intended to improve the health of entire populations. As resources are limited, infectious diseases are approached from a health protection framework with intensified surveillance, targeted interventions, more vaccines, and appropriate therapy. Acute care medicine, under similar financial stress, is now largely directed at fixing the evolving problems with pharmaceuticals and surgery, while the promotion of healthy lifestyles occurs with limited reference to social and ecological context. At the same time, less affluent people around the world are living in fear for their own health and safety, feeling more disempowered and disconnected from decision-makers.

Despite huge amounts of money being put into health care, the challenges facing public health multiply. It is time to examine diseases not just as problems in their own right, but also as markers of once healthy ecosystems that have lost their organisation, vitality, and resilience. The design of prevention and treatment strategies through this new perceptual lens, can contribute to a more efficient and effective model of public health.

Two recent Canadian events, of major consequence to human health, illustrate the inadequacy of traditional systemic strategies for preventing or responding to disease outbreaks:

the *E. coli* O157:H7 outbreak in Walkerton, Ontario and the SARS (Severe Acute Respiratory Syndrome) outbreak in Toronto.

This paper considers the conventional public health assessment of etiology and systems failure, offers an alternative assessment of failure and treatment from an ecosystem point of view, a new way of approaching such problems, and how to get there. An ecosystem approach, which considers biophysical, socioeconomic, political, and cultural factors, would lead to a better understanding of phenomena, and would help to both identify the origins of new epidemics and to design more effective preventative programmes.

Participatory health planning is part of the recipe for ecosystem approaches to health. Effective governance and planning is dependent on a healthy, participatory civil society--one that fosters 'communities of learning and knowledge through the establishment of trandisciplinary networks of collaboration' (Dale 2001:160). Such networks would also support a grounded system of communications which, among other things, might stimulate diverse, innovative, and informed public responses to environmental problem-solving—particularly in emergency situations.

The cases of Walkerton and SARS

In May-June 2000, in the town of Walkerton, Ontario (population 5,000), municipal water was contaminated by *E.coli* found in cattle feces, and introduced into the water source through rain runoff, leading to the deaths of at least seven people, hospitalising 68, and affecting the health of another 2000 people (University of Western Ontario, Ecosystem Health Website).

The SARS outbreak was caused by a coronavirus that likely originated in November 2002 in southern China. An infected man from Guandong province came to Hong Kong in

February and passed the disease to people who carried it to Vietnam, Singapore, and Canada. The contagion rapidly infected at least 8400 people and killed more than 800 worldwide; Toronto suffered 44 deaths and 375 known infections in two waves (SARS Commission Report 2006). Once SARS arrived, both the initial failure of control measures and its spread, were facilitated by the health system's inability to understand the exact nature of the mode of spread, and the high degree of infectivity of the causal coronavirus.

Both 'Walkerton and SARS-type' crises emerged from a social-ecological systemic failure. The case of the Walkerton crisis might be viewed as if it were merely a localised outbreak, largely the fault of a few under-trained, criminally negligent, individuals, or even as a 'fluke', attributable to chance, or the risks we run as an advanced society.

To an ecosystem thinker, however, the case is seen as a symptom of social-ecological systemic processes. The farm, which was the source of the Walkerton *E.coli* bacteria, is a well-run, mixed small family farm, with an excellent, implemented environmental farm plan. This situation arose from a combination of environmental, biological, and behavioral factors. They included inappropriate boundary-setting (the source of the bacteria was outside the town's political boundary but in its ecological boundary), and poor well placement. Torrential rainfall, an extreme weather event, led to the inability of the soil to drain adequately and to undergo natural filtration and the biological cleansing of pathogens. This extreme event may, in turn, have been related to global climate change. Moreover, government cutbacks and poorly-regulated privatisation, in both the health care and environmental regulatory systems, prevented adequate testing, and lack of local human capacity to monitor and interpret outcomes.

The Canadian outbreak of SARS, was not directly caused by local ecosystem disruption but introduced by a returning traveler. It represents the fact that local ecosystems are nested into

global ecosystems, and that diseases that arrive in airports or at hospital doors represent failures of public health. SARS was a disease which emerged from animals – probably bats (flying foxes) (Li et al. 2005) – within a context of massive, linked, social and ecological change. Many ecosystem thinkers believe that a SARS-like epidemic could have been anticipated at its origin in south China. Why?

The use of pteropid bats as food, and the co-mingling of domestic animals and wild species within densely populated urban markets, likely led to its spread into the human population in south China. Such local, intensified agricultural practices, responding to a market-created impetus to produce large volumes of low-cost food for urbanising populations, meet immediate goals (more chicken, more beef, more civet), but also result in the emergence of new pathogens (H5N1 influenza, SARS, Ecoli 0157:H7).

The details of exactly which organisms would take advantage of the opportunities afforded them by this system, might not have been predictable, but the high probability that epidemic infectious diseases could emerge was known, based on an understanding of complexity processes (Sommerville and Rapport 2000, Higginbothan et al. 2001), microbial adaptation, and ecological and biological first principles (Heymann 2005).

The human-to-human spread to Canada and elsewhere, thus occurred in a context of disruption on Chinese ecosystems due to local food demands and population pressures, but was facilitated by changes in how local ecosystems are connected globally -- a system of modern transportation, commerce, and socialisation -- each of which accentuated the risk.

Attention ought to have been paid to such disruption and restructuring of social-ecological systems, with unregulated demands for certain products promoting unsanitary conditions, all nested within a system of global trade and travel.

O*ther infectious threats*

Current concerns, for the spread of Highly Pathogenic Avian Influenza (HPAI) to human populations, exist in parallel to those of SARS, but with a much larger potential threat to humans should this particular virus opportunistically mutate with viability for human-to-human transmission. Ideal situations for emergence of HPAI, have been created by a combination of economies of scale as manifest in huge industrial chicken production factories, driven by regional and global commerce, mixed with traditional farming systems and social and ecological restructuring, which channels migratory birds to a few shrinking habitats.

An increasing number of organisms are making the transition from animal to human species. Of more than 1400 infectious agents pathogenic to people, 61 % are zoonotic (that is, transmissible between other vertebrates and people), and of 175 pathogenic agents described as 'emerging', 75 % are zoonotic (Taylor et al. 2001, Cox 2006). New diseases emerge through interactions among a wide variety of ecological social changes, including people invasion and colonisation of formerly wild areas heavy antibacterial and pesticide use, consumption of new species, and restructuring of urban and rural landscapes (Morse 2004)

Diseases, such as Ebola, continue to 'emerge', while humans colonise formerly wild areas under conditions of famine, eat 'bush meats', not normally part of a traditional diet, and as human-built environments merge with the natural (McNeill 1976). Lyme disease has emerged through complex interactions between economic policies that led to the abandonment of farmland, changes in species composition, and increased outside activities from people wishing to promote their own individual health.

The recycling of any biological materials through novel pathways, such as the global farm/slaughter/feed agrifood system, offers a striking example of the ways in which pathogens can multiply and be rapidly transmitted across large distances. We can not know yet whether the prion that causes scrapie in sheep, BSE (Bovine Spongiform Encephalopathy), and variant CJD (Creutzfeldt-Jakob Disease), might have followed the same progression, albeit a lot more slowly, under natural forces, rather than being accelerated greatly by the efficiency-recycling-driven process of feeding animal parts to a vegetarian species, cattle. However, since meat based, protein supplements, have been removed from the food chain in Britain, the incidence of new cases of BSE and CJD has dropped significantly (Manson et al. 2006**).**

The greater emphasis on economies of scale, to create efficiencies and profit in food production, has shifted industrialised societies from situations characterised by high-probability, low-consequence events, to low-probability, very high-consequence events. Economies of scale bring together large numbers of susceptible animals at one or more stages in the food chain, creating large ecological niches for opportunistic microbes; crowding increases shedding or various enteric organisms; antimicrobial treatments select for resistant strains; and distribution systems facilitate global distribution. Similarly, emphases on short-term economic profitability and efficiency, in response to public demands for low-priced meat and egg proteins, with no attention to basic tenets of biology or ecological context, resulted in epidemics of BSE in the UK (Nathanson et al. 1997). Food safety programmes have simply taken economies of scale as a given, and have structured responses (such as chemical, heat and radiation treatments in the production system, and hand washing in the home) to fit those, rather than examining the reasons for a large scale epidemic of, say, Salmonella enteritidis (Cogan and Humphrey 2003).

It certainly is appropriate and necessary to respond to acute needs, but it is dangerous to do so as if each was completely unpredictable and novel. Decision-makers need to go beyond reacting — they need to reduce the chances of other types of similar occurrences. All these examples suggest, that without effective recognition of how health is affected by complex systems interactions, institutional responses to epidemics will be incomplete, patchy, and, ultimately, will fall far short of the mark. Sustainable life-support for humans and other organisms, for example, includes the entire range of possible ecosystem functions, including provision of water, food, and disease control through biodiversity. Land-use, urban planning, and agriculture, are as important to public health outcomes as the institutions normally assigned to deal with health issues. Can a transdisciplinary ecosystem approach help with design of a better system?

What is an ecosystem approach to health?

Developing an effective institutional response, in this case to public health and epidemics, first requires a clear understanding of the phenomenon under consideration—in other words, a clear definition of health.

John Last (2006) has expanded the normative definition of health for public health practitioners - defining it as a 'sustainable state of equilibrium or harmony between humans and their physical, biological and social environments that enables them to coexist indefinitely. Implied is the capacity to adapt or adjust harmoniously to change in aspects of the environment'.

An ecosystem approach to human health is 'holistic', in that it explicitly anticipates disease and health outcomes within their complex social and ecological contexts, with respect to the ecological and cultural origins, vectors, propagation, response and natural mitigation. Like

the biological, hydrological, geomorphological, and climatic aspects of ecosystems (in common parlance, and elsewhere in this paper, often termed biophysical), social systems self-organise, and indeed, it is more useful to think of human social systems as embedded and interacting with the larger biosphere because, as in the case of human health, both the origins, and solutions to the chronic problems, are not solely in the human realm (Kay et al. 1999, Butler and Oluoch-Kosura 2006). As a result, an ecosystem approach deliberately crosses traditional jurisdictional, discipline, and professional boundaries (Carmen 2003) – this is not the norm in most health systems. Based on research over the past several decades, transdisciplinary models and tools have been developed to understand these phenomena (Parkes et al. 2006).

Neglecting to implement an ecosystem approach to agricultural and economic development programmes designed to improve health, may simply alter disease patterns by contributing to ecological imbalance. Malaria epidemics and cyclosporiasis, have each emerged in situations where ecosystems have been restructured to solve one set of problems, even as they create new ones (Waltner Toews 1999). A disease control programme in Bangladesh, designed to prevent cholera by building embankments against flooding, created new habitat for sand flies, thereby increasing infection rates with *Kala azar leishmaniasis* (Minkin et al. 1996). Even dams, built to generate electrical power to control flooding and to generate wealth (all of which are demonstrably supportive of health), may also expand or create new habitat for disease-causing flora and fauna, and remove sources of natural renewal (Oladejo and Ofoezie 2006).

Last (2006), adopting the notion of 'ecosystem distress syndrome' (Rapport et al. 1985), defines it as 'a situation that arises when the balanced equilibrium of an ecosystem is disrupted by a failure or interruption of an essential link or links in its chain of being' i.e. beyond which a state where the ecosystem could maintain itself. Such events can happen as a consequence of

human-induced pollution of a water source, introduction of exotic species, a change in prevailing temperature range and other environmental conditions, or many possible combinations of these variables (Rapport and Whitford 1999).

In any self-organised system, there are limits to resilience, thresholds for change will eventually be reached, and the equilibrium will end. Once a threshold has been crossed that exceeds capacity for replenishment (an unpredictable 'tipping point'), there can be a sudden, and often drastic, change in the state of the system (Folke et al. 2004). A grassland may become a desert. A forest reverts to a meadow. An ocean becomes depleted of commercial stocks of some fish species. A new disease emerges, or one is extirpated. A society changes – for good or bad. At an individual level, a person's health may suddenly shift from well to sick.

Outcomes can include species extinction, or reconstitution of the ecosystem in a new equilibrium, or both. It must be recognized that, while ecosystems under anthropogenic stress can adapt and re-organise and reconstitute and, thus, continue to exist, albeit in another form, the transformations, more often than not, have been shown to have negative consequences for human health and well being. Such situations are occurring at ever-accelerating rates. Jared Diamond's book, *Collapse* (2005), reflects on how such environmental change threatens human survival, using examples from Easter Island and Greenland historically, to contemporary Rwanda, Haiti and Montana. More careful attention must be paid to the links between social actions and ecological feedbacks, in the ways that both urban and rural landscapes are planned and structured, in order to prevent such negative consequences.

When this fails, ecological restoration (the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed) has the potential to mitigate infectious disease in humans, essentially fixing some of the impaired ecological functions or

structures, and reducing the impacts of diseases before they are uncontrollable (Fisher et al. 2001, Harris and Hobbes 2001). Ecological restoration of forested and meadow ecosystems, might reduce high densities of disease vectors that tend to favour the edges of fragmented habitats, if restoration created habitats for predators of the vectors, and caught urban and suburban rainwater. And it would do so, if restoration resulted in vegetated landscapes that held and processed water through soil, rather than allowing it to runoff into small urban pools (e.g. cans, storm drains), and which increases populations of disease carrying insect species.

Further, restored and increased buffers between human habitation, agriculture/animal husbandry and 'natural' areas, may make it less likely emerging diseases will jump between species (e.g.avian flu). This can, theoretically, be accomplished by isolating agricultural fowl from human dwellings, and lowering densities of animals in captivity, placing animals inside dedicated husbandry buildings or in pens, and restoring habitats, like wetlands, forests, and meadows, that wildfowl would be able to use if no longer able to access feedlots used by animals kept for food. By no means will all encounters between humans, husbanded animals, and wild animals cease, but these approaches would reduce contact drastically.

Doing this through economies of scale, however, as industrialised societies have done, requires mass inputs of energy (accelerating climate change and encouraging spread of other diseases), and simply dictating to small farmers that they should abandon their livelihoods is unworkable. An understanding of the social and ecological connections, and engagement of scientists and public health workers, with people living under duress in country-sides where these diseases are emerging, will facilitate the development of more effective and sustainable solutions.

The conventional public health approach to infectious disease: Surveillance, isolation, vaccine, therapy

Both Canadian and international public health authorities are calling for better organised and coordinated public health institutional structures that would enable rapid responses to the next pandemic. In the wake of the SARS crisis, but more directly, in preparation for the potential sparking of the next pandemic, the World Health Organisation (WHO) announced its revamped regulations, the International Health Regulations (IHR), governing the control of infectious disease. The revised IHR, now a part of international law, expanded regulations that previously applied only to cholera, yellow fever and plague. These regulations dictate minimum requirements for surveillance and response by member states. In addition, each country is to have the laboratory capacity to rapidly identify outbreaks and to implement specific measures to prevent disease spread at airports, seaports and other points of entry. A key goal was to improve coordination and communication between the WHO and member states. The WHO now requires that all countries give notification of 'all events potentially constituting a public health emergency', regardless of cause (Anonymous 2004). The WHO has also developed its Global Influenza Preparedness Plan in line with these principles(WHO 2005). These conclusions may be valid, but is there evidence that they are achievable and, if so, will they lead to intended outcomes?

Large scale, pro-active initiatives, aimed at preventing pandemics , have often proven ineffective. Surveillance, programmes require adequate buy-in from populations, which requires responding to local needs. There must be a level of trust in the system as well as a corporate ownership of health issues. For any disease surveillance system to be sustainable, individuals have to be educated enough to recognize when they are ill. They have to want to report to someone who can make a diagnosis. That person has to make the diagnosis, decide to document

that diagnosis, and then report it further up the chain. At each step in the reporting hierarchy, diagnostic capacity is required (knowledge, appropriate technology), as is the will to report. Even in the best of all possibly imagined contexts (well educated citizens in an open democracy), people will only report events if there is some compelling reason for them to do so (e.g. they will get better care, for instance, or the communities in which they live will gain improved overall health, perhaps through food and water supplies). In particular, the reporting of a disease must not lead to punitive measures. For example, the reporting of a case of mad-cow disease may lead to a farmer's herd being slaughtered, thereby a loss of livelihood. A response to HPAI, which does not deal with small-holder farmers and their livelihoods, and extended social networks, as well as with cock-fighting and other alternative uses of poultry, is likely to cause far more social upset and disease than the epidemic will allegedly prevent.

Critics of 'common sense' approaches, represented by the IHR, may remember that institutional responses to combat swine flu, plague, and the triumvirate of Marburg, Ebola, and Lassa fever, were ineffective, costly, and, in some cases, went seriously wrong (Priest 2005). Even today, the response to HPAI, for instance, has often combined promotion of economies of scale and culling of local birds. Economies of scale simply scale up the size of the epidemics, and reports emerging from Turkey now suggest that local culling in some villages has removed the chickens as a tick-predator, and has resulted in outbreaks of tick-borne diseases.

Immunization is often considered as a panacaea. The massive immunization campaign for swine flu in the US, appears to have contributed to far more incidents of Guillain Barré syndrome than lives saved (Crossen 2005). Canada's first experiment in universal, free flu vaccine, which cost Ontario taxpayers more than $50 million annually for five million vaccine doses a year, does not appear to have reduced laboratory-diagnosed cases of flu. Cases rose from

109/100,000, in the ten years prior to the campaign's launch in 2000, to 164/100,000 in the five years after the launch. Further, the rate did not change relative to other provinces (Groll and Thomson 2005). Supporters of the vaccine programme point out that in this study only laboratory-confirmed cases were included, meaning that actual flu might have been reduced, but cases were not tested and recognized as frequently prior to the campaign. However, during the study period, most cases of flu did not appear to have been caused by the specific serotypes of virus represented in the vaccines, meaning that the vaccine may have been effective at doing what it was supposed to, but that the predictors of the strains to include in the vaccine [CDC, WHO] missed the predominant strain of concern at the time.

Conventional public health approaches can minimize the consequences of a pandemic, but the capacity for doing so is unevenly distributed and resides mainly in economically privileged countries. Some voices in the developing world consider the new WHO International Health Regulations. at best, to be an attempt to minimize the fallout on rich countries, rather than addressing the problem holistically (Sivaram 2005). With the prospect of a coming pandemic, it is highly likely that rich countries, as well as poor ones, will be at risk, and approaches, including the current global stockpiling of Tamiflu among the 'well to do', to ward-off a potential H5N1 pandemic in rich countries may, in hindsight, prove to be equally misguided.

If even a portion of funds, currently invested in anti-viral drugs, vaccines, surveillance and programmes in developing countries, were invested in building local, social and ecological resilience in south and east Asia, an HPAI epidemic might be prevented at the source. This approach contrasts with extreme measures, like mass pesticide applications, wholesale destruction of infected areas or populations to prevent further spread, or similar approaches familiar from wildlife management and perhaps agriculture.

Population health and an 'ecosystem approach'While the field of ecosystem health, as it is known today, developed within the last three decades (Rapportet al. 1979, Rapport 1989), a holistic approach to the determinants of public health can be found in the writings of Rudolf Virchow over 150 years ago. Virchow's recommendations to the Prussian government, to deal with a typhus epidemic in Upper Silesia, included political reform and local self-government, education, economic reform, agricultural reform, development of cooperatives, roadbuilding, and a requirement that professionals speak the language of the local people (Drotman 1998). Today, most decision-makers, medical practitioners, and informed observers, recognize the importance of addressing the primary determinants of health, including social and biophysical environments.

Population health considers the importance of individual health care, but extends the single patient view, understanding the distribution of disease and health in the whole population, population subgroups, regions and communities (community medicine, public health medicine), and the importance of the social support network, education, and the health of the environment, as key modifiable factors in human health (APHA website). To this end, it realizes the necessity of limited interdisciplinary cooperation with several public health disciplines, such as social sciences, health economics, environmental, ecological and life sciences. In particular, the international dimensions of health and illness have to be considered in this age of globalisation and information technology.

Population health advocates have pushed public health decision-makers into recognizing complex interactions of determinants of health. The public health community is now trying to explain to policy-makers the serious consequences of minimising taxation and, thus, infrastructure, deregulating laboratories, and downloading responsibilities, without regard to

developing local capabilities, and the undermining of social capital, which leads to poorly-trained and uneducated water monitors and fractured communications. On a larger scale, both crises, SARS in Toronto and *E. coli* in Walkerton, may be symptoms of unchecked globalisation of the economy with minimisation of infrastructure support and maximisation of productivity. So, isn't an ecosystem approach merely properly-practiced public health or population health?

The public health mandate is seemingly boundless; officials are entrusted with disease prevention, health assessment, surveillance, monitoring, protection and promotion, and, ideally, with policy development formulation and advocacy, though often without resources . Effective public decision-making, and administrative processes, must be able to anticipate and respond to the complex system dynamics which characterise the contemporary health policy arena. The challenge for public health is to know how to 'institutionalise', legitimise, and implement, approaches that are pluralistic, systemic, and complex, as well as how to get there in terms of organisation, policy and administration. To do so requires an ability to think outside the conceptual and institutional straightjackets that characterise today's public health system.

It is in precisely these types of situations that an integrated ecosystem approach might be useful: to design a robust system, including the development of more effective communication and governance systems, that can anticipate or possibly prevent and absorb shocks when such events cannot readily be mitigated, laying the groundwork for essential proactive strategies that help to anticipate and deal with systemic public health problems as well as unforeseen crises.

Governments, professionals, and the public, look for tangible, and often immediate, results—results that can be measured and based on immediately perceivable benefits in terms of human health outcomes and resource expenditure efficiencies. Current public health approaches tend to be 'top-down', and even a 'successful' surveillance and disease-control system may

accentuate local dependence on outside expertise, decrease local capabilities to respond rapidly, and undermine local health and democracy. These responses externalise the social-ecological determinants which gave rise to the disease in the first place, and may often create greater (or at least equally serious) problems than the ones they are intended to 'solve'.

In contrast, an ecosystem approach links an understanding of ecological systems and social systems and the ways in which they are inextricably linked. It also involves 'buy-in' from local communities, and tends to be aimed at helping communities to anticipate and adapt to changing social and ecological conditions, rather than to predict and control (Gunderson and Holling 2002, Waltner-Toews 2004, Walker et al. 2006). An ecosystem approach differs from the usual population health approaches through a renewed emphasis on the complex interconnections within which health and disease are defined, and suggests management further upstream, long range planning, and administrative responses.

As much as health workers fighting to control HIV/AIDS have (re)discovered, the international public health community will need to learn that sustainable disease control programmes can only emerge from community engagement coupled with systemic social-ecological understanding. Resilience in public health can only be achieved through building local capacity and diffused expertise, as opposed to an expensive 'top-down' expert-driven system.

Implementing the ecosystem approach

What, then needs to be done? Globally to locally, a shift is needed from conventional, institutional silos, with authoritarian 'expert' decision-makers to participatory, democratic, nested, 'systems' approaches to health . Public dialogue is required, involving various

stakeholders, government, experts, local communities, and trans-disciplinary thinkers, to determine priorities, attempt consensus making, and create new conceptual frameworks, that incorporate all of the relevant inputs. Choices must be made to balance health promotion with health protection activities. This may require patience and perseverance, but in the end decision-making becomes more spontaneous and genuinely democratic and, therefore, more resilient.

Public participation, in and of itself, is not necessarily a guarantee that the ultimate policy approaches will necessarily lead to ecological sustainability. A system that encourages a form of participatory (or discursive) ecological democracy, however, does offer a constructive approach to public engagement. Coined by John Dryzek (2005), ecological democracy refers to a cooperative, participatory community problem-solving approach, that includes an open, reflexive, participatory policy dialogue, leading to continuous social learning and self-monitoring. The on-going discussion is centred on the interests of the community as a whole (rather than individual self-interest), including its biophysical needs.

Movement is required in three broad areas, all of which are interdependent. They include, 1) philosophical and paradigmatic shifts in the public health arena, 2) the adoption of effective communications and educational strategies, and 3) institutional changes in health administration.

1) Philosophical perspectives

At a conceptual level, the aim must be to help communities to anticipate and adapt, rather than to predict and control. We must recognize that when full functions of ecosystems are compromised, the loss of function (and structure) of natural systems often extends to human constructed systems, such as agroecosystems and urban ecosystems. To put this in the economic

language of decision-makers, our society tends to manage ecosystems for one dominant good or service, such as fish, timber, or hydropower, without fully realizing the trade-offs we are making, including some as yet unevaluated or unvalued in the marketplace, such as biodiversity and flood control. A transdisciplinary ecosystem approach considers the entire range of possible goods and services, and attempts to optimize the mix of benefits for a given ecosystem and also across ecosystems. This perspective places a value on ecosystem services, internalises costs, and views production of goods and services as the natural product of a healthy ecosystem, not as an end in itself.

Health, in itself, is affected by multiple sectors of society. Health, therefore, cannot be viewed as something that can be promoted through single solutions, or through separate organisations or facilities, operating as silos; any approach or solution must take place with the understanding that health problems originate from local sources to the global context. This means that continuing extreme global social inequity will not only have serious ethical considerations for Canadian decision-makers, but this situation will also have a direct negative impact on the health of all individuals living within Canada.

The conundrum, as stated earlier, is how to find ways of incorporating 'grassroots participation' into decision-making processes that are also responsible, effective, and efficient. This cannot simply take place by devolving or offloading responsibility to decision-makers who might not have the education, resources, capacity, or will, to effectively oversee public health. Long term sustainability and ecosystem health need to be based on the philosophical principles of 'proportionality' (actions that are appropriate to the scale of a problem) and 'subsidiarity' (actions that are taken at the appropriate level closest to the citizens) (Meadowcroft et al. 2005). One well-known example of this is the Healthy Communities Movement that began as the

Healthy Cities Project in Toronto in 1984. By 1988, over 300 local governments and communities in Canada (and 1000 worldwide) had adopted the vision expressed by Healthy Communities, which suggested that local government had:

> 'a critically important role to play in determining the quality of life of communities and the health of the people who live in them; that capacity for individual health is largely dependent on environmental quality[1]; and that the more equitably the benefits of social and economic development are distributed among people, the better the health of the general population will be' (Wismer 1996).

The healthy communities movement has had many different applications. In some cases, the principles were seen as general goals that local governments should keep in mind when making policy. To others, it was often seen as a blueprint for guiding the community into the future. Within the urban context, regional and local decision-making can improve health, for example, through economies of scale in housing, transportation, and energy use.

While several models and approaches have been developed to address the promotion of social-ecological resilience or health (Gunderson and Holling 2002, Waltner Toews 2004),, the ecosystem model developed by Trevor Hancock (1997), and (which is) reflected by the Healthy Communities movement, is probably the most accessible to public health workers. Hancock's model is based on a set of interdependent concerns, where individual health is nested within the family, the community, and the ecosystems which support them. This model placed health at the conjunction of community conviviality, environmental viability, and economic adequacy, and their inter-relationships with ecological sustainability, livability of the built environment, and social equity (Hancock 1997:43). A consideration of transportation policy (Hancock 2000), that would meet the six criteria in the model, suggests that a good public transit system would be a

healthier public policy than one that encouraged private car use**.** It would reduce energy use and greenhouse gas emissions, reduce harmful air pollution, encourage bike ridership and pedestrian traffic, leading to healthier, more livable public spaces. By encouraging more social action it would become more convivial; more affordable for people disadvantaged by such factors as low income; more equitable; have reduced financial costs associated with the provision of health services related to injuries, congestion, air pollution; and reduce financial costs associated with road repair.

2) Communications and education

Not only is work needed to prevent catastrophic events, but decision-makers need effective communications and governance systems in order to be prepared to deal with such events when they happen. Moreover, they must also be prepared to absorb the shocks when they cannot be readily mitigated.

In the case of Walkerton, the government of the day dismantled what it had perceived as 'expensive' redundancies in the original system. These actually represented a vital system of checks and balances. When that system was violated, crucial feedback loops were broken, and laboratory surveillance and public health became separated, thereby delaying responsiveness and disempowering local decision-makers. An essential element of that system had been a communications network between decision-makers and actors, that included reporting, testing, and monitoring, at various levels of decision-making authority.

Despite some prior experience with the outbreak, the second wave of SARS in Toronto was also characterized by poor communication between governments, practitioners, local communities, and international bodies. As this crisis unfolded, institutional and structural

deficits were apparent to one of us (NA), working as a local on call hospitalist, in a medium-sized Ontario city. Quarantine was arbitrarily and inconsistently applied between and within hospitals. A lack of staff education, with respect to technique and rationale, and complete non-participation with decision-making, led to less than adequate implementation. Changing regulations in response to political, rather than medical, concerns compounded the situation.

In an ecosystems approach, communications and governance are quite different from the conventional, vertically integrated, institutional structures, as opposed to horizontal connections between agencies, including health care institutions, social services, educational institutions, urban planning, public health, etc. Different scales of planning from local to global must be engaged; there has to be effective communication and cooperation between health promotion and protective aspects of health. For public health programmes to be effective, they must engage the civic community, and those providing the basic data must understand the systemic context sufficiently in order to guide and support sustainable, responsive interventions (Parkes et al. 2006).

Public education is required to modify societal behaviour and expectations as to how we live. Examples include limiting development in critical source-water areas, revisiting the scale of farm and industrial operations, and appropriately pricing food to include the environmental and human costs of production. Environment and health regulations do mean higher prices to producers and consumers but are necessary to prevent ecosystem degradation and human health problems.

Healthy communities must also be nested within a system of governing that recognizes the 'appropriate role' of other governments and actors in decision-making. In addition, as Meadowcroft, Farrell and Sprangenberg (2005) suggest, such a system would need to include

'the formulation of clear objectives at various governance levels, their implementation in terms of targets and interim goals, measurement through indicators, and the monitoring of performance'.

3) Institutional changes: From government to governance

An active, healthy, civic environment, requires the support of formal institutional mechanisms that translate public ideas and visions into practical policies that feed back into public forums and 'healthy' community initiatives. How do we introduce these concepts, into an institutional arena that is founded on economics, disciplinary boundaries, and short-term solutions, to meet political pressures that occur as a result of four-year term governments?

Governments, structures and administrations *can* change if there is popular and political will. When societal values change, Pfahl (2005) observes, institutions also have to change or evolve; otherwise, they lose their ability to act as intermediary agents that coordinate human action. Some might refer to this as 'institutional learning', although institutions themselves also shape societal values.

Throughout the world, we are now witnessing growing public pressure for more local control, public participation, and education, in decisions which most affect community residents. Such philosophical changes are taking place in all organisations, not just the public health arena. Even if it has yet to be translated into practice, many organisations, including transnational companies and international agencies such as the World Bank, are increasingly acknowledging the growing global impact of civil society organisations (World Bank 2006).

The shift in public values, that pressures for institutional response and change, may either evolve over time or be a reaction to a particular perceived, or real, crisis, such as Walkerton or

SARS. Inquiries into both crises were followed by recommendations, and actions have been taken at the international, regional, and domestic levels of governance.

In Canada, Justice Archie Campbell identified many systemic failures with the institutional response to SARS: a system that was 'unprepared, fragmented, poorly led' and 'inadequately resourced', with a '…lack of laboratory capacity, the absence of a public health communications strategy, poor coordination with Ottawa, confusion about liability and legal responsibilities, and the system's inability to handle a sudden surge in demand for health services'(The SARS Commission 2006).

Campbell's key recommendations included: identifying safe water and food, and infectious disease prevention as first priorities for the government; setting up a centre for disease control in Ontario; bringing together academics, public health experts and laboratory services to cope with infectious disease outbreaks; increasing provincial funding for public health agencies around the province; and ending the bickering with the federal government over who has responsibility for public health. He concluded that if the government 'lacks the necessary political will, it can tinker with the system, make a token investment, and then wait for the death, sickness, suffering and economic disaster that will come with the next outbreak of disease' (Mallan 2004). The federal government's Naylor report (Krawchuk, 2003, Naylor et al. 2003), and The Expert Panel on SARS and Infectious Disease Control chaired by Dr. David Walker, arrived at similar conclusions (Walker et al. 2004).

One institutional response to the Naylor, and other reports, was the creation of the Public Health Agency of Canada. The new Agency's mandate explicitly recognizes the need for a collaborative, coordinated approach, between various institutions and jurisdictions, federally and internationally - and sees Canada as part of a global community (PHAC 2004). There are many

as yet unanswered questions about how well the new body will be able to achieve its mandate within the Canadian federal system, or with respect to the broader international health regime.

For proponents of the ecosystem health approach, the Agency's current emphasis is limiting, focused as it is on the prevention of infectious and chronic diseases rather than some of the broader determinants of ecosystem and public health. Resilience in health systems, local, national, and global, can only be achieved through building local to globally scaled capacities with diffused expertise. This approach to health 'governance' must also receive institutional support from governments, which in turn must coordinate their activities across departments (not just health), administrative divisions, and jurisdictions. The establishment of this body, however, does signal recognition that governments can, and do, respond to societal pressures. Moreover, in this situation, the government has been nudged towards taking a more collaborative approach than might otherwise have been the case.

A reconceptualisation of health might include everything that humans participate in – socially, environmentally, economically and politically. As such, it requires multiple scales of planning and action, both over time and across geographies, in order to address the health of diverse populations. Dynamic communicating networks of people, with different types of expertise and abilities, have to be in place to have an adaptive, responsive system, that can be alert to important biophysical and socio-economic, local, and global cues, that could profoundly affect vital ecological systems and their inhabitants.

An ideal system would bring all stakeholders together, in order to engage in a public dialogue on trade-offs and management, within the best scientific understanding of ecological constraints. These include transdisciplinary thinkers, and a variety of communities of interests within administrative systems, that emphasise horizontal agency connections. Involving local

communities, that have an interest in prudent stewardship, can help promote equitable distribution of the benefits and costs of ecosystem use. It would recognize the crucial role to be played by civil society, encouraging a multiplicity of perspectives and active engagement in the formation of public policy (Dale 2001:123-127). Once a commitment is made to implement this approach, it must be backed up by well-placed champions to ensure that effective administrative, regulatory, education, and communications systems, are in place—systems that can address the complex forces that currently influence the global state of public health today.

The approach also involves re-envisioning the roles of institutions and practitioners, with non-health care personnel involved in health care decision making, and health care personnel involved in other sectors of society that affect health. The traditional fixed institutions of health care (hospitals, home care, public health) must become much more fluid and cooperative, focusing on the mission of regional health care rather than on their own institutional missions. Regional health teams will not just be comprised of traditional health care practitioners, but will include economists, educators, public administrators, politicians, urban planners, and environmental scientists, among others. These teams have to be given the capacity and resources to best meet the health needs of people and their communities. The individuals on the team need to be trained to be effective team players in these truly holistic health-teams.

In the new 'transdisciplinary umbrella' paradigm, primary health care practitioners will serve not only in their traditional role of individual or family health care provider, but must also begin to serve as 'health detectors', identifying illnesses that require solutions beyond the health care system. While health care providers may see their influence in health care and proportional budget allocation diminished, the scope and importance of their work, and the scope of their influence and what is considered 'health', would actually expand.

Evidence of change

Ecosystem approaches to health have yet to be effectively adopted and implemented in any systematic way on a larger scale. Many small scale, 'real world' examples, include elements of this approach (De plaen et al. 2004). New processes and administrative structures are emerging, based on mechanisms such as 'roundtables' and consensus-based decision-making approaches that are diverse, adaptable, and resilient, and can respond to change. Community development programmes, with participatory decision-making, are often favoured in developing world settings, even by institutions, from the WHO to the World Bank (WHO website 19955, World Bank website 2007). These processes also can lead to alternative avenues of influence, that operate both within and outside the formal structures of local governments. For example, a series of research and public engagement programmes in the 1990s in Kathmandu, Nepal, moved from consideration of a single parasitic disease to a social-ecological rejuvenation of a seriously degraded downtown area (Waltner Toews et al. 2005).

In Canada, the Federal Provincial Territorial Advisory Committee on Population Health has issued reports on the health of Canadians, and is trying to incorporate some of these approaches, rather than a purely rational, top down, approach (Healthy Canadians website). In Sweden, the first objective domain of public health policy to guide officials at all levels is participation and influence in society (Swedish National Institute of Public Health website 2003). Some public health units are taking it upon themselves to challenge traditional ways. In eastern Ontario, a health unit led an effort to bring together community groups, acute and chronic care providers, experts, and other stakeholders, to determine health priorities with the Lanark Leeds Grenville Health Forum (Gardner et al. 2005). In Walkerton itself, Concerned Walkerton Citizens got together with experts and government officials to research, analyse, educate, and

advocate (Canadian Water Network website). At a macro level, Sweden is trying to move beyond a highly-detailed technocratic structure to a high level participatory one.

Conclusions

Although the example of infectious disease was used here, a similar analysis might be applied to other complex public health related issues, from food security to air quality to urban sprawl. Holistic models are being developed to allow practical application in terms of policy development based on the best science, decision-making and evaluation (Van Leeuwen et al. 1999). Existing local services in health care and public health must be coordinated and structured in a way that embraces community engagement and transformative education.

The ecosystem approach can bring together the most current scientific understanding of ecosystems with community participatory approaches, to help people resolve situations in which problems and solutions interact in complex and often surprising ways. It also emphasizes the need for more dynamic, inclusive policy/decision-making processes within government institutions that are supportive of more holistic approaches. It recognizes that traditional institutional approaches to protect and promote health are limited when they operate in a vacuum.

The ecosystem approach demands patience and perseverance, but its results can typically be implemented in a more spontaneous and natural way, since the community, decision-makers, and scientists, are directly involved in defining the problem and identifying solutions. It is well within the realm of practical public policy to address many problems proactively, before they become intractable or require expensive 'after the fact' medical clean-ups.

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References

Anonymous (2004) Public-health preparedness requires more than surveillance. *The Lancet*, 364 (9446), 1639-1640, 6 November.

Butler, C.D. and Oluoch-Kosura, W. (2006) Linking future ecosystem services and future human well-being. *Ecology and Society,* 11 (1):30. Available at http://www.ecologyandsociety.org/vol11/iss1/art30/ Accessed April 15, 2007.

Carmen, B. (ed) (2003) Health: An Ecosystem Approach International Development Research Centre. Available at http://web.idrc.ca/en/ev-29348-201-1-DO_TOPIC.html. Accessed April 15, 2007.

Cogan, T.A. and Humphrey, T.J. (2003) The rise and fall of Salmonella enteritidis in the UK. *Journal of Applied Microbiology*, 94 (supplement), 114s-119s.

Canadian Water Network Concerned Walkerton Citizens. (2005) Available at http://www.cwn-rce.ca/?fa=News.showPublicHealthForum-SymposiumAgenda Accessed April 15, 2007.

Cox, S. (2006) Infected Planet AlterNet, Posted on March 21, 2006. Available at http://www.alternet.org/story/33703/. Accessed April 15, 2007.

Crossen, C. (2005) Déjà vu: Political Action, Folly Greeted the Outbreak Of Swine Flu in 1976. *Wall Street Journal,* November 28, p. B1.

Dale, A. (2001) *At the Edge: Sustainable Development in the 21st Century* (Vancouver and Toronto: University of British Columbia Press, p.160).

De Plaen, R., Mergler D. and Rapport, D. (eds) (2004) Lessons from the International Forum on Ecosystem Approaches to Human Health - Toward a Common Vision). *EcoHealth*, Volume 1, Supplement 2, Dec. .

Diamond, J.(2005) Collapse: How Societies Choose to Fail or Succeed (New York: Viking).

Drotman, D.P, (1998) Emerging Infectious Disease A Brief Biographical Heritage. *Emerging Infectious Diseases,* 4(3).372-373

Dryzek, J. (2005) *The Politics of the Earth, 2nd edition* (New York: Oxford, 197-201).

Fisher, W.S., Jackson, L.E., Suter, G.W. and Bertram, P. (2001) Indicators for human and ecological risk assessment: A US environmental protection agency perspective. *Human and Ecological Risk Assessment,* 7 (5), 961-970.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S. (2004) Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review in Ecology, Evolution and Systematics*, 35, 557-581.

Gardner, C., Arya, N. and McAllister, M.L. (2005) Can a Health Unit take Action on Broad Determinants of Health. *Canadian Journal of Public Health,* 96(5), 374-379.

Groll, D.L. and Thomson, D.J. (2006) Incidence of influenza in Ontario following the Universal Influenza Immunization Campaign. *Vaccine*, 24(24), 5245-5250

Gunderson, L.H. and Holling, C.S.A. (2002) *Panarchy: Understanding Transformations in Human and Natural Systems* (Washington: Island Press).

Hancock, T. (ed)(1997) *Healthy Sustainable Communities: Concept, Fledgling Practice, and Implications for Governance, Eco-City Dimensions: Healthy Communities, Healthy Planet* (Gabriola Island B.C.: New Society Publishers).

Hancock, T. (2000) Urban Ecosystems and Human Health A paper prepared for the Seminar on CIID-IDRC and urban development in Latin America Montevideo, Uruguay April 6-7). Available at http://www.idrc.ca/en/ev-22828-201-1-DO_TOPIC.html Accessed April 15, 2007.

Harris, J.A. and Hobbs, R.J. (2001) Clinical practice for ecosystem health: The role of ecological restoration. *Ecosystem Health,* 7(4), 195-202.

Healthy Canadian. Available at http://www.healthycanadians.ca/BkgDisc-e.html#toc. Accessed April 15, 2007.

Heymann, D. (2005) Social, behavioural and environmental factors and their impact on infectious disease outbreaks. *Journal of Public Health Policy,* 26, 133-139.

Higginbothan, N., Albrecht, G. and Connor, L. (2001) *Health Social Science: A Transdisciplinary and Complexity Perspective* (Melbourne: Oxford University Press).

Kay, J., Regier, H., Boyle, M. and Francis, G. (1999) An ecosystem approach for sustainability: Addressing the challenge of complexity. *Futures*, 31, 721-742.

Krawchuk, C. (2003) Federal Report: Learning from SARS, Renewal of Public Health in Canada, CBC News Online, Oct. 7. Available at http://www.cbc.ca/news/background/sars/sars_report.html Accessed April 15, 2007.

Last, J.M. (2006) *Dictionary of Public Health* (New York: Oxford University Press).

Li, W, Shi Z, Yu M, Ren W, Smith, C., Epstein, J.H., Wang H, Crameri, G., Hu Z, Zhang H, Zhang J, McEachern, J., Field, H., Daszak, P., Eaton, B.T., Zhang S and Wang L (2005) Bats are natural reservoirs of SARS-like coronaviruses. *Science*, 310, 676.

Mallan, C. (2004) Scathing report blasts health chiefs. Judge singles out Dr. Colin D'Cunha, *Toronto Star* Frontline workers got little help. April 21.

Manson, J.C., Cancellotti, E.C., Hart, P., Bishop, M.T. and Barron, R.M. (2006).. The transmissible spongiform encepalopathies: Emerging and declining epidemics. *Biochem. Soc. Trans,* 34, 1155–1158.

McMichael, T. (2001) *Human Frontiers, Environments and Disease.* (Cambridge: Cambridge University Press).

McNeill, W.H. (1976) *Plagues and People* (New York: Anchor).

Meadowcroft, J., Farrell, K.N. and Spangenberg, J. (2005) Developing a Sustainability Framework for Sustainability Governance in the European Union. *International Journal of Sustainable Development*, 8(1/2), 3-11.

Millennium Assessment Report (2005) Available at http://www.millenniumassessment.org/en/index.aspx

Minkin, S.F., Rahman, R. And Islam, M.A.(1996) Flood control embankments and epidemic kala-azar in Bangladesh. *Ecosystem Health*, 2, 215-226.

Morse, S. (2004) Factors and determinants of disease emergence. *Revue Scientifique et Technique-Office International des Epizooties* ., 23(2), 443-451. Available at https://www.oie.int/eng/publicat/rt/2302/PDF/443-452morse.pdf
Accessed April 15, 2007.

Nathanson, N., Wilesmith, J. and Griot, C. (1997) Bovine Spongiform Encephalopathy: Causes and consequences of a common source epidemic. *American Journal of Epidemiology*, 145, 959-969.

Naylor D. and the National Advisory Committee on SARS and Public Health (Basrur S, Bergeron MG, Brunham RC, Butler-Jones D, Dafoe G, Ferguson-Paré M, Lussing F, McGeer A, Neufeld KR Plummer F) (2003) Learning from SARS - Renewal of Public Health in Canada. Available at http://www.phac-aspc.gc.ca/publicat/sars-sras/naylor/index.html, Accessed April 15, 2007.

Oladejo, S.O. and Ofoezie, I.E. (2006) Unabated schistosomiasis transmission in Erinle River Dam, Osun State, Nigeria: Evidence of neglect of environmental effects of development projects. *Tropical Medicine & International Health,* 11(6), 843-850.

.

Parkes, M., Bienen, L., Breilh, J., Hsu, L-N., McDonald, M., Patz, J., Rosenthal, J., Sahani, M., Sleigh, A., Waltner-Toews, D**.** and Yassi, A. (2006) All Hands on Deck: Transdisciplinary Approaches to Emerging Infectious Disease. *EcoHealth*, 2, 258-272.

Pfahl, S. (2005) Institutional Sustainability. *International Journal of Sustainable Development,* 8(1/2), 80-96.

PHAC (Public Health Agency of Canada) (2004) Frequently Asked Questions. *News Release,* September 2004, available at http://www.phac-aspc.gc.ca/media/nr-rp/2004/faq_e.html.

Priest, A. (2005) Panic Is for the Birds: The recent flu flap may be Chicken Little for some, a golden goose for others. Available at http://www.shared-vision.com/2005/sv1812/ birdflu 1812.html.

Rapport, D.J. (1989) What constitutes ecosystem health? *Perspectives in Biology & Medicine,* 33, 120-132.

Rapport, D.J. and Whitford, W. (1999) How ecosystems respond to stress: Common properties of arid and aquatic systems. *BioScience,* 49(3), 193-203.

Rapport, D.J., Regier, H.A. and Hutchinson, T.C. (1985) Ecosystem behaviour under stress. *The American Naturalist,* 125, 617-640.

Rapport, D.J., Thorpe, C., and Regier, H.A. (1979) Ecosystem medicine. *Bulletin of the Ecological Society of America*, 60, 180–182.

SARS Commission (2006) Available at http://www.sarscommission.ca/. Accessed April 15, 2007, quotes from interim report.

Sivaraman, S. (2005) Health, wealth and terror. *Third World Resurgence*, No. 179 (July). Available at http://www.phmovement.org/en/node/121 Accessed April 15, 2007

Somerville, M.A. and Rapport, D.J. (eds) (2000) *Transdisciplinarity: reCreating Integrated Knowledge* (UK: EOLSS Publishers Co. Ltd., Oxford).

Swedish National Institute of Public Health (2003) Sweden's New Public Health Policy. Available at http://www.fhi.se/upload/PDF/2004/English/newpublic0401.pdf. Accessed April 15, 2007

Taylor, L.H., Latham, S., Woolhouse, M.E.J. 2001. Risk factors for human disease emergence. *Philosophical Transactions of the Royal Society of London* 356: 983-989.

.

University of Western Ontario. Ecosystem Health Case Studies, Available at http://www.med.uwo.ca/EcoSystemHealth/education/casestudies/walkerton.htmAccessed April 15, 2007

Van Leeuwen, J.A., Waltner-Toews, D., Abernathy, T. and Smit, B. (1999) Evolving Models of Human Health Towards an Ecosystem Context. *Ecosystem Health*, 5(3) 204-219, September.

Walker, B.H., Anderies, J.M., Kinzig, A.P. and Ryan, P. (2006) Exploring resilience in social-ecological systems through comparative studies and theory development: Introduction to the special issue. *Ecology and Society,* 11(1) 12 Available at http://www.ecologyandsociety.org/vol11/iss1/art12/ Accessed April 15, 2007.

Walker, D and the Ontario Expert Panel on SARS and Infectious Disease Control (2004) Report for the Public's Health – A Plan of Action, April 21. Available at http://www.health.gov.on.ca/english/public/pub/ministry_reports/walker_panel_2003/walker_panel.html , Accessed April 15, 2007.

Waltner-Toews, D. (1999) Mad Cows and Bad Berries. *Alternatives Journal: Environmental Thought, Policy and Action*, 25, 38-44.

Waltner-Toews, D. (2004) Ecosystem Sustainability and Health: A Practical Approach (Cambridge: Cambridge University Press).

Waltner-Toews, D., Neudeorffer, C., Joshi, D.D. and Tamang, M.S. (2005) Agro-urban ecosystem health assessment in Kathmandu, Nepal: Epidemiology, systems, narratives. *Ecohealth*, 2, 1-11.

Wismer, S.(1996) Women and community-building in Kitchener-Waterloo. In T. Bunting, K. Curtis and P. Filion (eds) *Dynamics of the Dispersed City: Perspectives on the Kitchener Metropolitan Region*(Waterloo, On: Department of Geography, University of Waterloo, 355-372).

World Bank website (2007) "Community Driven Development: Overview" Available at http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTCDD/0,,contentMDK:20250804~menuPK:535770~pagePK:148956~piPK:216618~theSitePK:430161,00.html, Accessed April 15, 2007.

World Health Organization (2005) WHO Global Influenza Preparedness Plan.Re;\port http://www.who.int/csr/resources/publications/influenza/WHO_CDS_CSR_GIP_2005_5/en/

World Health Organization website (1996) Available at http://www.who.int/docstore/water_sanitation_health/Environmental_sanit/PHAST/phast96-11/PHASTAnnexD.htm Accessed April 15, 2007

Note

[1] Some believe that talking of environmental quality is 'dated' thinking- A throw back to a time when environment was partitioned into air, land, and water, and 'quality' was measured by the absence of 'contaminants' with 'contaminant free' as the ultimate standard. Some ecosystems are relatively contaminant free (i.e. have good water, air, land quality) and yet are entirely dysfunctional owing to overharvesting, introduction of exotics, or other non-pollutant stresses. Now many recognize this as a highly limited definition. Environmental quality today should be looked at in terms of ecosystems that have maintained their full 'functions' and full potential for adaptability to changing environments. By this criteria, most of the planet is rapidly losing 'environmental quality'.