Chapter 18
Infectious Disease in the Arctic: A Panorama in Transition

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Abstract Many interconnected factors are responsible for the continuing and growing importance of infectious diseases in the Arctic. Many of these factors not only contribute to the risk of infectious diseases but also are broad determinants of the populations overall health. In the last part of the nineteenth and first part of the twentieth centuries, infectious diseases were major causes of mortality in Arctic communities. However the health of indigenous peoples of the circumpolar region has improved over the last 50 years. Despite these improvements, rates of viral hepatitis, tuberculosis, respiratory tract infections, invasive bacterial infections, sexually transmitted diseases, infections caused by *Helicobacter pylori*, and certain zoonotic and parasitic infections are higher in the Arctic indigenous peoples when compared to their respective national population rates. More recently the climate and ecosystem driven emergence of climate sensitive infectious diseases and disease patterns in the Arctic region presents an emerging challenge to those living in the Arctic. As in other parts of the world, a key component of prevention and control of infectious diseases is surveillance. The use of circumpolar health networks, together with effective coordinated surveillance can facilitate timely control of infectious disease outbreaks, inform public health officials' decisions on resource allocation, provide data to adjust prevention and control strategies to maximize their effects, and inform future research needs.

Keywords Arctic • Circumpolar health • Infectious diseases • Indigenous peoples • Climate change

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18.1 The Arctic Environment and Populations

The Arctic is home to four million people of whom almost half reside in northern part of the Russian Federation. People in the Arctic live in social and physical environments that differ from their more southern dwelling counterparts. Approximately 400,000 (10 %) of persons are of indigenous ancestry, half of whom live in the northern part of the Russian Federation (Arctic Human Development Report 2004; Parkinson et al. 2008).

The indigenous populations of northern Canada, Alaska, Greenland and the northern Russian Federation generally reside in remote isolated communities consisting of 150 to several thousand inhabitants. In some regions the only access to communities is by small aircraft or boat in summer and by small aircraft and snow machine in winter. Indigenous peoples of Scandinavia live in the northern parts of Norway, Sweden, and Finland, but their life styles are more similar to those of the populations of the southern parts of Scandinavia. Arctic communities on a whole, once isolated, are now very much a part of the global village we all live in and are as vulnerable to health threats as any other community on the globe. Through their unique relationship with nature, many of these peoples are more vulnerable for health threats generated by climate change.

These communities often have little economic opportunities and are still largely dependent on subsistence harvesting of wildlife resources from terrestrial, fresh water and marine ecosystems for a significant proportion of their diet. Food security is often dependent on subsistence wildlife migration patterns, predictable weather, and some method of food storage. In these remote regions access to public health and acute care systems is often marginal and poorly supported.

The disease pattern described in this chapter mainly describes that of the indigenous populations of northern Canada, Alaska, and Greenland, both as this pattern is quite different from those of their more southern neighbours, and as of the northern populations most is known about these groups.

18.2 The Panorama of Infectious Diseases

Many interconnected factors are responsible for the continuing and growing importance of infectious diseases in the Arctic: changes in the size and composition of the population (overcrowding, migration, from rural communities to urban centers); changes in personal behaviors (increased travel, substance abuse, and risky sexual behavior) health care practices (increasing use of antibiotics) and changes in the physical environment (contamination of subsistence foods, climate change and greater human contact with altered wildlife habitats). Many of these factors not only contribute to the risk of infectious diseases but also are broad determinants of the populations overall health.

In the last part of the nineteenth and first part of the twentieth centuries, infectious diseases were major causes of mortality in Arctic communities. The small geographically isolated communities provided some protection, but when a new pathogen was introduced epidemics frequently followed. In Alaska outbreaks of influenza and influenza like-illness were frequent in the nineteenth century often occurring with European or American whalers and merchant ships during the summer months (Fortuine 1989). The “great sickness” epidemic of the 1900, a combined measles and influenza outbreak, resulted in the death of one quarter of Alaska’s Eskimo population but barely affected the non-native population. In October of 1918 the Spanish flu was introduced to Nome Alaska by ship from Seattle, Washington. Some smaller surrounding villages (Brevig Mission) lost 85 % of their population within 5 days (Reid et al. 1999). In 1925 more than half of all deaths in Greenland were caused by acute infectious disease and tuberculosis. Similarly in 1934 in Alaska the annual death rate for tuberculosis among Alaska Natives was 655 cases per 100,000 persons, compared to 56 per 100,000 for non native persons (Fortuine 2005).

In Canada a major measles epidemic reached Baffin Island in 1952 and the Ungava peninsular in northern Quebec following Inuit visitors to the armed forces base at Goose Bay Labrador, infecting 99 % and killing between 2 and 7 % of these remote populations (Peart and Nagler 1952). The first cases of measles did not appear in Greenland until 1945 but occurred as a result of increasing plane travel to Greenland whereby infected persons could reach the country while still infectious. Complications included pneumonia, otitis media, and meningitis. In 1955 the incidence of tuberculosis in Greenland reached 2,300 cases per 100,000 persons, and similar figures were seen in native populations of Alaska and Canada. It was during this era that large scale population based intervention programs were mobilized to combat tuberculosis and these programs began laying the foundation of the modern public health system in these regions (Fortuine 2005; Wherret 1945; Stein 1994).

The health of indigenous peoples of the circumpolar region has improved over the last 50 years or so. Much of this improvement can be attributed not only to the implementation of prevention and treatment activities that have resulted in reductions in morbidity and mortality from infectious diseases, such as tuberculosis, and the vaccine preventable diseases of childhood, but also to the provision of safe water supplies, better housing conditions and sewage disposal in many communities.

However despite these improvements, rates of viral hepatitis, tuberculosis, respiratory tract infections, invasive bacterial infections, sexually transmitted diseases, infections caused by *Helicobacter pylori*, and certain zoonotic and parasitic infections are higher in the Arctic indigenous populations of the circumpolar north when compared to their respective national population rates (Koch et al. 2008).

The high rates of tuberculosis in Aboriginal populations in Alaska, Canada, and Greenland in the early to mid-1900s are well-documented (Fortuine 2005; Wherret 1945; Stein 1994). However since that time improved screening and continued maintenance of robust surveillance systems, have resulted in decreasing rates of tuberculosis in Alaska, Canada and Greenland (Funk 2003; Njoo 2000; Søborg et al. 2001; Skifte 2003; Thomsen et al. 2003; Birch, et al. 2014).

However outbreaks continue to occur with one likely explanation being reactivation of latent tuberculosis infection often masked as other respiratory ailments common in the population (Funk 2003) and fueled by persistently poor living conditions (Clark et al. 2002; Nguyen et al. 2003). Recent rates of disease reported in Alaska increased from 8.9/100,000 population in 2005 to 10.4/100,000 in 2006 (Centers for Disease Control and Prevention 2007). In Canada, the overall rate of tuberculosis in 2002 was 5.2/100,000 population, however regional variations vary, rates ranged from less than 1/100,000 population in Nova Scotia to 93.4/100,000 population in Nunavut (Public Health Agency of Canada 2005). Multi Drug Resistant-tuberculosis occurs rarely in these regions and is found most frequently in immigrant populations in Canada and the U.S., however, there is concern that it will spread to the general population including the Aboriginal populations which are most affected by tuberculosis (Centers for Disease Control 2007; Moniruzzaman et al. 2006; Public Health Agency of Canada 2004).

In 1954 Greenland increased biannual screening, introduced mass BCG vaccination of Neonates, established tuberculosis sanatoriums and sent patients to Denmark for treatment. Efforts resulted in a dramatic decline in rate of tuberculosis comparable to other western countries and was lowest in 1985 (25/100,000 population). Following this success tuberculosis interventions were phased out. And by 1997, the incidence of tuberculosis had doubled. Following two fatal cases of TB meningitis in children BCG vaccination was resumed and a national intervention program was launched in 2000 (Søborg et al. 2001; Skifte 2003; Thomsen et al. 2003). The incidence has steadily increased since then to reach a maximum of 205 cases per 100,000 in 2010 with 14 % of 10th grade school children TB infected, figures similar to those of Nigeria, Myanmar and DR Congo. (Yearly Report 2012 Office of the Chief Medical Officer of Greenland).

Persistently high tuberculosis rates continue in northern populations and are partly due to risk factors such as persistent poverty and crowded living conditions as well as reactivation of latent tuberculosis, often miss-diagnosed as other respiratory ailments in these populations. Improved screening and the development and continued maintenance of robust surveillance systems are essential to control tuberculosis. A new blood test (the gamma interferon assay) for the detection of latent infections may improve diagnosis in these regions.

All five types of viral hepatitis (A, B, C, D, and E) have been found in Arctic regions. In most Arctic regions, HAV has become rare due to successful vaccination programs coupled with improved water and sanitation. Routine HBV vaccination has dramatically reduced HBV rates in several regions, such as Alaska, Canada, and the Russian Federation. Greenland is considered a high endemic region where horizontal HBV transmission remains. A particular HBV subgenotype B6 has recently been identified in the Eastern Arctic (Sakamoto et al. 2007). However, after implementing routine HBV vaccination in 2010, the possibly changing HBV epidemiology in Greenland deserves further evaluation. High prevalence's of HCV continue to be seen in some urban parts of the Arctic region and are linked to recent increases in drug use, mainly among the young population. The outcome of HCV disease is worsened by alcohol abuse. HDV and HEV are not reportable in the Arctic region.

HDV has been reported as a major contributing factor in liver cirrhosis in the Russian Federation. In Greenland, HBV/HDV co-infection, resulting in severe disease, is a concern; it is hoped that the recent introduction of universal HBV vaccination will improve this situation. Possibly due to infrequent testing, only a few cases of HEV (mainly imported) have been recorded across the Arctic Region (Langer et al. 1997; McMahon and Blystad 2013; Fitzsimmons et al. 2013).

Upper and lower respiratory tract infections cover a wide spectrum of infections from common colds to severe life threatening influenza and pneumonia and are common cause for hospitalization. Alaska Native and American Indian people living in Alaska have an average of three- to fourfold higher mortality rates due to pneumonia and influenza than non-Alaska Native persons (Groom et al. 2009). Alaska Native people remain at high risk for early and substantial morbidity from pandemic influenza episodes (Wenger et al. 2011). During the 2009 pandemic influenza A (H1N1) epidemic, in rural regions of Alaska, disease occurred earlier, than other regions, and Alaska Native people were two to four times more likely to be hospitalized than non-Natives. Although reasons are not fully understood, increased household crowding, especially during dry cold fall and winter, lack of running water for handwashing, may facilitate transmission of respiratory pathogens, and greater remoteness, distance between population centers and health care facilities may delay care and result in increased mortality. Other Arctic indigenous populations including the Canadian First Nations people appear to have increased rates of 2009 H1N1 (Kumar et al. 2009; Charania and Tsuji 2011).

Alaska Native and Canada Inuit infants experience one of the highest reported hospitalization rates for lower respiratory tract infections globally (Singleton et al. 2010; Banerji et al. 2013). The incidence and prevalence of childhood respiratory tract infection in Greenland exceeds rates found in many developing countries (Koch et al. 2002). Few studies have been undertaken to determine the microbiologic causes of respiratory tract infections. Although a number of viral agents have been found in hospitalized Alaska Native and Canadian Inuit children with lower respiratory tract infections, Respiratory Syncytial Virus (RSV) appears to be the leading cause of hospitalization and long term sequelae in young children. However in a recent study in western Alaska, human metapneumovirus and parainfluenzavirus type 1 were also common and were associated with more severe illness (Singleton et al. 2010). Again these infections are commonly associated with environmental factors such as household crowding and lack of running water and result in a significant morbidity, chronic sequelae including bronchiectasis and high cost of hospitalization (Banerji et al. 2013).

Indigenous populations of the Arctic are at particular risk for several invasive bacterial diseases. *Streptococcus pneumoniae* is a leading cause of pneumonia, bacteremia, sepsis, and meningitis in these populations. In the US Arctic and northern Canada the rate of invasive pneumococcal disease among indigenous persons is four times that of non-indigenous persons (Bruce et al. 2008; Degani et al. 2008). While there are more than 90 different serotypes of *Streptococcus pneumoniae* it has been estimated that more than 80 % of pneumococcal disease occurring in the US Arctic, northern Canada, and Greenland are potentially preventable through the use of the

23-valent polysaccharide vaccine in adults and the 13-valent conjugate vaccine in children less than 5 years of age providing the rationale for implementation of vaccine programs in most Arctic countries. *Haemophilus influenzae* can cause meningitis, bacteremia, respiratory tract infections otitis media, sinusitis, epiglottis, pneumonia and septic arthritis. Among the six serotypes (a–f), *Haemophilus influenzae* type b (Hib) was the most common cause of childhood meningitis prior to the introduction of the *Haemophilus influenza*e type b vaccine in the early 1990s. Prior to 1991, rates of invasive Hib disease in Alaska Natives were the highest in the world with rates >300 cases per 100,000 in those under 5 years of age, four times the non-Native rate in Alaska. Since the introduction of the Hib conjugate vaccine programs in 1991 the rates of invasive Hib disease has declined by 98 %. Universal vaccine programs in Canada began in 1992 and in Greenland in 1997 and have had a similar impact (Bruce et al. 2008; Degani et al. 2008; Meyer et al. 2008). As a result most invasive *Haemophilus influenzae* disease in the north is now caused by non Hib strains and in Alaska and Canada in particular Hia has emerged as an important cause of this disease. Continued surveillance of invasive disease caused by all serotypes of *Haemophilus influenzae* is needed to monitor the continued success of Hib vaccination and the continuing emergence of Hia and other serotypes in these populations (Bruce et al. 2013).

Another cause of meningitis in Arctic Regions is *Neisseria meningitidis*. While sharp epidemics occur sporadically, the incidence of meningococcal disease in Alaska, northern Canada and Greenland has remained stable at 1–2 cases per 100,000 per year with children under 5, and young adults having the highest risk. The majority of disease is caused by serogroups B and C. Multi-valent vaccines containing groups A, C, Y and W-135 are available, and a new conjugate group B vaccine licensed for use in Europe is under evaluation for use in other countries (Zulz et al. 2014).

Illnesses caused by group A Streptococcus range from upper respiratory infections, skin infections, or occasionally more severe and life threatening diseases such as necrotizing fasciitis and toxic shock syndrome. Between 2000 and 2010, 488 cases were reported from northern Canada and the US Arctic, with an 11 % case fatality rate. Highest rates occurred in children <2 and those over 65 years of age. Two cases were reported from Greenland, and 54 cases from northern Sweden (Zulz et al. 2014). There is no vaccine to prevent group A infections. Control depends on case detection and antibiotic therapy and prophylaxis in close contacts to prevent further spread.

Group B Streptococcus can also cause a range of diseases, such as bacteremia, sepsis, pneumonia, meningitis, and various conditions associated with pregnancy. Between 2000 and 2010 346 cases were reported from the US Arctic and northern Canada, with an overall fatality rate of 10 %. Bacteremia was the most common clinical presentation. The highest rate occurred in children <2 (Zulz et al. 2014).

Of the sexually transmitted diseases gonorrhea and chlamydial infections are the most common in Arctic populations, highly transmissible, and if untreated can lead to significant morbidity, especially in women (pelvic inflammatory disease, ectopic pregnancy and infertility). In Greenland, following systematic intervention consisting of contact tracing and treatment, rates of gonorrhea have declined from a high of 20,700 per 100,000 persons in the late 1970s to about 1,100 per 100,000 in 2004. Rates are still 100 times rates in Denmark, and remain the highest in Arctic regions (Gesink-Law et al. 2008). In 1973 Alaska rates of gonorrhea were 913 cases per 100,000 persons. In 2008 the overall rate had declined to 85 cases per 100,000, however rates in Alaska Native persons remain higher at 300 cases per 100,000 (State of Alaska 2009). In 2010 overall rates were 179 cases/100,000. Infection rates were highest among AI/AN females and males (915 and 588 cases per 100,000 persons, respectively) (State of Alaska 2011). In northern Canada in 2006 rates of gonorrhea were 281 cases per 100,000, and in northern Quebec the incidence rate of Gonorrhea was 1,000 cases per 100,000, almost ten times the National rate (Gesink-Law et al. 2008).

Similarly chlamydial infections continue to be a challenge for public health in Arctic regions. In Greenland chlamydia infections became notifiable in 1995. Since then the incidence has doubled to 3,400 per 100,000 between 2000 and 2004, ten times the rate in Denmark (Gesink-Law et al. 2008). In Alaska rates have steadily increased since the mid-1990s from 307 in 1998 and exceed 660 per 100,000 in 2005. Rates in Alaska Natives are considerably higher. In 2012 rates were 749 cases per 100,000, with rates of 3267 and 1132 cases per 100,000 in Alaska Native females and males respectively. Continuing interventions include increased community and provider awareness through educational outreach efforts, disease intervention services, and expedited partner therapy (State of Alaska 2013). In northern Canada rates of chlamydial infection were 1,922 cases per 100,000 ten times the National rate (Gesink-Law et al. 2008). A critical component of controlling STD epidemics involves promptly locating, notifying and treating all sex partners with antimicrobials. This has been a challenge for public health providers, especially in geographic areas where partner services are not available or when patients are unwilling or unable to participate.

While much of the improvement in the health of indigenous peoples of the circumpolar region can be attributed to the advent and liberal use of antimicrobial agents that have resulted in reductions in morbidity and mortality from infectious diseases, overuse of antimicrobials has resulted in the emergence of bacterial strains that are now resistant to these agents. In Alaska the percentage of invasive isolates of *Streptococcus pneumoniae* demonstrating full resistance to penicillin increase from <1 % in 1993 to almost 15 % by 2000. However this trend has been reversed by the introduction in 2001 of pneumococcal conjugate vaccines that eliminated those serotypes most common in infants that were most resistant to penicillin. For the time period 2000–2006, 5 % of isolates were resistant to penicillin in the US Arctic, <3 % in northern Canada, but <1 % from Greenland, Iceland and northern Sweden (Zulz et al. 2014).

Once considered to be an infection only acquired in health care settings methicillin–resistant *Staphylococcus aureus* (MRSA) infection acquired in the community is an emerging public health challenge in the Arctic especially in small remote communities where household overcrowding, frequent skin to skin contact, challenges to personal hygiene, sharing of personal contaminated items, limited access to adequate in-home running water, sanitation services and health care are common. In Alaska a large outbreak of *Staphylococcus aureus* skin infections were reported in 1999 from several communities in south western Alaska. The majority (86 %) of infections were MRSA. Those infected were more likely to have had received antibiotics in the previous year, and used an MRSA contaminated sauna (Baggett et al. 2004). It is believed that antibiotic pressure from a drug resistant strain carrying a particular cytotoxin producing gene Panton-Valentine Leukocidin (PVL) led to the emergence and spread of MRSA in these remote communities of south western Alaska. In northern Canada community acquired MRSA was first reported among an Aboriginal community in Alberta in 1986 (Taylor et al. 1990). Since 1983 the incidence of MRSA has increased in small indigenous communities in northern Manitoba (Larcombe et al. 2007), northern Saskatchewan (Golding et al. 2011) and in the remote Inuit community of Nunavut (Dalloo et al. 2008). The cases in these areas reveal a similar epidemiology with predominance in younger age groups, skin and soft tissue infection, and similar MRSA strains exhibiting the virulence cytotoxin PVL. In Greenland only sporadic cases have occurred (Statens Serum Institut, Copenhagen, Denmark).

Chronic *Helicobacter pylori* infection increases the risk of peptic ulcer disease and gastric cancer and is of increasing concern among northern communities and health care providers. The prevalence of *Helicobacter pylori* infection in Arctic Countries is very high with high rates in many indigenous populations. Studies in the US Arctic have found the seroprevalence of *Helicobacter pylori* infection is significantly increased among Alaska Native peoples (75 %) overall compare with non-Native Alaskans (24 %) (Parkinson et al. 2000; Lynn et al. 2007). Similarly estimates of *Helicobacter pylori* seroprevalence in Aboriginal communities in northern Canada range from 50 to 95 % (Goodman and Jacobson 2008), and in Greenland the seroprevalence is 58 % in persons 15–87 years of age (Koch et al. 2005). Studies in non-Arctic populations have shown that *Helicobacter pylori* can be treated successfully using a combination of 2 or more antimicrobials resulting in cure rates of between 60 and 95 % (McMahon et al. 2014). However in Alaska, prior use of commonly used antimicrobials has been associated with increasing rates of resistance and treatment failure (McMahon et al. 2003; Bruce et al. 2006). Reinfection following apparently successful treatment is also common in regions with a high prevalence of infection. In a 2 year study of Alaska Natives seeking treatment for *Helicobacter pylori* infection, there was a 14.6 % reinfection rate after 2 years of successful treatment (McMahon et al. 2003, 2006). Since rates of antimicrobial resistance to agents used to treat *Helicobacter pylori* are high and increasing, use of these agents in high prevalence populations could lead to increasing antimicrobial resistance not only to *Helicobacter pylori* but also to other common bacterial agents such as *Streptococcus pneumoniae*, *Staphylococcus aureus* and *Haemophilus influenzae*. More information on the risk factors associated with *Helicobacter pylori* infection, treatment and preventive strategies are needed from Arctic communities in other circumpolar countries.

A number of parasitic infections with potential to infect humans are endemic in wildlife in Arctic regions (Jenkins et al. 2013). Trichinellosis is caused by the freeze resistant nematode *Trichinella nativa* transmitted by intake of infected raw or undercooked game meat, in particular polar bear and walrus. Human outbreaks occur, and Canada implemented a prevention program in the 1990s (Proulx et al. 2002). Echinococcosis disease caused by *Echinococcus granulosus* and *Echinococcus multilocularis* occurs in wildlife in Alaska, Canada, Northern Norway, Sweden, and Finland, but not in Greenland. Wolves, foxes and dogs are definitive hosts (Jenkins et al. 2013). Other parasites causing disease in Arctic populations include Giardia, Cryptosporidium, Toxoplasma, Ascaris, Anisachis, and Diphyllobotrium (Jenkins et al. 2013). Rabies in Arctic areas has been known for over 150 years and is endemic in Arctic wildlife, mainly foxes, but human cases are very rare (Mørk and Prestrud 2004).

18.3 Climate and Environmental Change and Infectious Diseases

The Arctic, even more so than other parts of the world, warmed substantially over the twentieth century, principally in recent decades. According to the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC 2013), climate models predict continued warming in the coming decades, with even greater warming in the Arctic resulting in a mean increase between 1.5 and 5.8 °C by 2,100. With these projected mean global temperature increases, it is likely that the Arctic sea ice cover will continue to shrink and thin, the winters will warm more so than summers, the mean annual precipitation will increase, global glacier volume will decrease, and the Northern Hemisphere spring snow cover will decrease during the twenty-first century (IPCC 2013). Continued melting of permafrost and sea ice is expected to augment river discharge and contribute to a rise in sea level by 1 m by 2,100. Moreover, some predictions suggest that these changes will be accompanied by greater overall climate variability and an increase in extreme weather events (Arctic Council ACIA 2005).

The current level of warming in the Arctic has already brought about substantial ecological and socioeconomic impacts, caused by the thawing of permafrost, flooding, shoreline erosion, storm surges, and loss of protective sea ice (Brubaker et al. 2011). In many Arctic communities, the physical infrastructure was built on permafrost. Weakening of this permafrost foundation will likely damage water intake systems and pipes, and result in contamination of community water supplies. Moreover, the failure of the foundation of access roads, boardwalks, water storage tanks, and wastewater treatment facilities can turn water distribution and wastewater treatment systems inoperable. In the US Arctic (Alaska) reduced access to treated water for hygiene has already been shown to result in increased hospitalizations for skin respiratory tract infections and pneumonia (Hennessy et al. 2008; Wenger et al. 2010) A number of Alaskan villages are already threatened by relocation due to the failing of foundational support for houses, water systems, and civil infrastructure (Warren et al. 2005; Brubaker et al. 2011).

A shift in the boundaries of climatically and geographically linked ecosystems (biomes) will result in new habitats for plants, insects, and animals with profound implications for human activity. It is likely that the ecology and epidemiology of infectious disease will change as well. Climate and weather affect the distribution and risk of many vector-borne diseases, globally, such as malaria, Rift Valley Fever, plague, and dengue fever in more southern latitudes (Semenza and Menne 2009; PAHO and WHO 2012). Weather also impacts the distribution of food- and waterborne diseases and emerging infectious diseases, such as West Nile virus, hantavirus, and Ebola hemorrhagic fever, etc. (Brookes et al. 2004; Pinzon et al. 2004; Haines et al. 2006; Dearing and Dizney 2010; Money et al. 2010). However, less is known about the influence of climate change and the risk and distribution of infectious diseases in Arctic regions (Hueffer et al. 2011; Revich et al. 2012; Revich and Podolnya 2011). Nevertheless, it is likely that the climate change impacts could result in changes of rates of respiratory infections, skin infections, diarrheal diseases, and many other conditions caused by bacterial, viral, and parasitic agents (Evengard et al. 2011; Brubaker et al. 2011; Hennessy et al. 2008; Wenger et al. 2010; Dudarev et al. 2013a; Tokarevich et al. 2012). Specifically, rising temperatures are expected to favor a northward expansion of boreal forest into the tundra, and of tundra into the polar desert (Arctic Council ACIA 2005). Increasing temperatures may thus shift the density and distribution of animal hosts and arthropod vectors which could result in an increase in human illness or a shift in the geographical range of disease caused by these agents (*Echinococcus* spp., *Francisella tularensis*, West Nile virus, Hantaviruses, and tick-borne encephalitis viruses, *Borrelia burgdorferi*, arboviruses including Sindbis virus, California serogroup viruses) (Hueffer et al. 2013; Revich et al. 2012, Parkinson 2008; Ahlm et al. 2013; Campagna et al. 2011; Ryden et al. 2011). A 2014 report from northern Alaska documented an increased risk to residents of contracting infectious diseases transmitted by wildlife (Goyette et al. 2014). Invasive bacterial infections are of special concern in the Arctic (Bruce et al. 2013; Helferty et al. 2013). Rising temperatures may allow reservoir host animal species to survive winters in larger numbers, increase in population size and expand their habitat range. Such shifts can favor the transmission of *Brucella* spp., *Toxoplasma gondii, Trichinella* spp. *Coxiella burnetti* and Puumala hantavirus to humans in more northern locations (Parkinson 2008; Parkinson and Evengard 2009; Evander and Ahlm 2009; Tokarevich et al. 2012; Kersh et al. 2012). In 2004 an outbreak of gastroenteritis caused by *Vibrio parahaemolyticus* from oysters grown in Alaskan waters occurred. This outbreak extended by 1,000 km the northernmost documented source of oysters that caused illness due to *V. parahaemolyticus with* rising temperatures of ocean water seeming to have contributed to the outbreak (McLaughlin et al. 2005).

Many Arctic residents depend on subsistence hunting, fishing and gathering for food and a stable climate for food storage. Food storage methods often include above ground air-drying and smoking of fish and meat at ambient temperature, below ground cold storage on or near the permafrost, as well as fermentation. Changes in climate may prevent the proper drying of fish or meat, resulting in spoilage (botulism) and contributing to food borne disease outbreaks (McLaughlin et al.

2004). Similarly loss of permafrost may result in spoilage of food stored below ground (Brubaker et al. 2011). Loss of these traditional food storage methods will also contribute to reduced food security for many Arctic communities (Nilsson et al. 2013; Dudarev et al. 2013b).

Changes in global and Arctic climate may result in increased transport of persistent organic pollutants and other toxic metals to the Arctic (Kirk et al. 2012). Bioaccumulating contaminants in animals can impact their survival, affect their immune responses, their possible role as reservoirs of zoonotic agents, and pose a food-safety risk if they are animal species hunted for food (Fisk et al. 2005; McDonald et al. 2005; Proulx et al. 2002).

18.4 Prevention and Control-Use of Existing Networks

The climate and ecosystem driven emergence of new infectious diseases and disease patterns in the Arctic region presents a continuing challenge to those living in the Arctic and to the public health and health care provider communities. However the Arctic is unique in that Arctic countries have a long history of international collaboration and cooperation when dealing with issues that affect their communities including human health. The International Union for Circumpolar Health (www.iuch.net) is a non governmental organization comprised of associations of five circumpolar health organizations which can trace its origins back to the 1960s. The IUCH promotes cooperation on human health through activities of 13 working groups, including infectious diseases and promotes communication through the International Journal of Circumpolar Health (www.circumpolarhealthjournal.net) and a triennial Congress on Circumpolar Health. The Circumpolar Health Research Network (www.circhnet.org) is a network of researchers, research trainees, supporters of research based in academic institutions, indigenous peoples organizations, and regional health authorities who share the goal of improving health of the residents of the Arctic region through international cooperation in health research. The Arctic council (www.arctic-council.org), established in 1996, is a ministerial intergovernmental forum which promotes cooperation among the eight Arctic states (including indigenous communities and other Arctic residents) on issues relating to sustainable development and environmental protection. Human health is embedded in two working groups: The Arctic Monitoring and Assessment Programs (AMAP) Human Health Assessment group which tracks the impact of environmental pollution on human health, and the Sustainable Development Working Groups (SDWG) Human Health Experts Group which has the role of fostering sustainable development by ensuring good health and wellbeing of indigenous communities and other residents of the Arctic (Parkinson 2010).

As in other parts of the world, a key component of prevention and control of infectious diseases is surveillance. Effective surveillance can facilitate timely control of infectious disease outbreaks, inform public health officials' decisions on resource allocation, provide data to adjust prevention and control strategies to maximize their effects, and inform future research needs.

Using these established international collaborations the International Circumpolar Surveillance of Emerging Infectious Diseases (ICS) system was initiated in 1998. This was initially an Arctic Council, SDWG IUCH project that aimed to link public health laboratories, institutes and academic centers for the purpose of monitoring and sharing standardized information on infectious diseases of concern, collaborating on research and prevention and control activities across the circumpolar north (Parkinson et al. 2008; Zulz et al. 2009). Initially a working group was established for surveillance of invasive bacterial diseases in northern populations (Bruce 2008) and has been instrumental in demonstrating the effectiveness of pneumococcal vaccines in circumpolar populations, and detecting the emergence of non type b serotypes *Haemophilus influenzae* invasive disease in children in both Alaska and northern Canada (Tsang et al. 2014). ICS research working groups have since been formed for collaborative work on diseases caused by *Helicobacter pylori* (McMahon et al. 2014), and viral hepatitis (McMahon and Blystad 2013). A tuberculosis surveillance working group was formed in 2007 to improve surveillance, identify trends of tuberculosis in the north, assess incidence, improve awareness and collaborate on research (Bourgeois et al. 2013). In 2010 an ICS Climate Change and Infectious Disease Working Group was formed to share information on climate sensitive infectious diseases in the circumpolar North (Parkinson et al. 2014 White paper). The Arctic provides a unique opportunity to use a "one health" approach as an organizing concept to understand the disease ecology and the potential impact of climate on disease occurrence in both human and animal populations in Arctic regions and to expand local, regional, and international networks to increase interdisciplinary collaboration and understanding about climate change and infectious disease emergence, prevention and control (Aenishaenslin et al. 2014; American Medical Veterinary Association 2008; Dehove 2010) The working group provides the opportunity to bring together public, wildlife, and environmental health professionals from other Arctic Council Working Groups such as CAFF, PAME, and other networks and organizations such as the WHO, CDC and ECDC, to share information on activities related to the impact of environmental change on human and wildlife health, and to provide a forum for identifying ideas and areas of common interest and collaboration at the local regional and circumpolar levels.

18.5 Conclusions

Arctic societies are societies in change. During the twentieth century traditional life styles have been rapidly changing towards those of western life styles including improved economic, housing, and sanitation conditions, facilitation of travels, and improvement of health systems and preventive measures. These changes have affected the traditional pattern of infectious diseases exemplified by e.g., reduction of the previously very high rates of tuberculosis.

Yet, climate changes are expected to influence the infectious disease pattern of the Arctic. It is likely that increasing temperatures may result in increasing rates of respiratory, skin infections, diarrheal diseases, zoonoses, and a range of other bacterial, viral, and parasitic agents.

Such influence may be carried out through a number of possible mechanisms. Northwards expansions of boreal forest and tundra following increasing temperatures may shift the density and distribution of animal hosts and arthropod vectors leading to higher rates of diseases in humans associated with these factors. Reservoir host animals may survive winters and increase in population size. Changes in global and Arctic climate may lead to increased transport of persistent organic pollutants and other toxic metals to the Arctic. Bioaccumulation of these substances in animals may affect their survival, their possible role as reservoirs of zoonotic agents, and pose a food-safety risk if they are animal species hunted for food. Traditional Arctic food storage methods may be inadequate for food safety in case of warming temperatures. Destruction of physical infrastructure that in many places is built on permafrost may have detrimental effects on sanitation and water supply. Facilitated travel conditions through e.g., melting of sea ice may favor introduction of microbiological agents from the outside world and facilitate their spread.

While a warming climate may have beneficial societal effects through e.g., improved travel conditions and new occupational possibilities such as agriculture, the health effects of a warming climate in the Arctic are not expected to be generally positive.

At present there is little firm knowledge of health effects in Arctic populations following global warming. Such warming is, however, expected to pose a major challenge to human health, and to the collaborations that study these effects and devise and implement possible prevention and control measures.

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