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What's In the Water? Climate Change, Waterborne Pathogens, and the Safety of the Rural Alaskan Water Supply

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Introduction

The majestic glaciers, pure oceans and rivers, and panoramic scenic views of Alaska so well known now to the world's population are disappearing as the current pace of climate change is melting the glaciers, intruding sea water into coastal and riparian rural Alaskan communities, and changing the landscape of Alaska's interior.[1] As the glaciers melt and sea water levels rise, flooding events will become more frequent and dramatic, and the rural Alaskan communities built on the coast or riverbanks will be particularly susceptible to these flooding events.

Even more importantly, flooding may contaminate the surface and groundwater sources that these communities rely on for drinking water and sanitation, potentially bringing waterborne infectious disease pathogens such as *Cryptosporidium* and *Giardia* into these water sources. The health impact of floods depends on public health infrastructure, water supply infra-

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1. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 487 (2005).

structure, and human behavior.[2] If Alaska does not protect these water sources, change the existing water supply infrastructure, and increase community public health education for these rural communities before more numerous climatic flooding events take place, there is a real danger of permanently destroying these rural communities.

Current climate projections identify a mean increase in global temperature of between 1.5 and 5.8°C over the next century, which will lead to increased variation and severity of extreme rainfall, temperature events, and changing patterns of hydrology.[3] Although the entire United States will be affected by these changes, Alaskan climate change is now, and will continue to be, far more pronounced than climate change in the lower forty-eight states.[4] Arctic ambient temperatures have already warmed at two times the rate of the rest of the world in the past two decades.[5] Alaskan glaciers are responsible for at least seven percent of the global sea rise over the past century, raising the level of Earth's oceans by more then one-tenth of a millimeter each year.[6] The melting of the Arctic sea ice is feeding atmospheric, oceanic, and hydrolytic cycles throughout the world.[7] In Alaska, climate change can be seen in changes in precipitation magnitude and frequency, reductions in sea ice extent and thickness, and climate warming and cooling.[8]

The communities in rural Alaska will experience climate changes more pronounced than the rest of the United States, as these areas have a more sparse population, harsh climate, and seasonal extremes.[9,10,11] One-sixth

2. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 147-148 (World Health Organization) (2003).

3. E.P. Hoberg et al., *Pathogens of domestic and free-ranging ungulates: global climate change in temperate to boreal latitudes across North America*, 27 REV. SCI. TECH. OFF. INT'L EPIZ. 511, 515 (2008).

4. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 474 (2008).

5. Allen J. Parkinson et al., *Potential Impact of Climate Change on Infectious Disease in the Arctic*, 64 INT'L J. CIRCUMPOLAR HEALTH 478, 479 (2005).

6. Ned Rozell, *Alaska Glaciers Show Dramatic Melting*, Alaska Science Forum, Dec. 2001, http://www.gi.alaska.edu/ScienceForum/ASF15/1572.html

7. Magdalena A.K. Muir, *Ocean and Fisheries Law: Ocean and Climate Change: Global and Arctic Perspectives*, 7 SUSTAINABLE DEV. L. & POL'Y 50, 52 (2006).

8. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 487 (2005).

9. *Id*.

10. *Id*.

11. Allen J. Parkinson, *The International Polar Year, 2007-2008, An Opportunity to Focus on Infectious Diseases in Arctic Regions*, 14 EMERG. INFECT. DISEASES 1,1 (2008).

(116,000) of Alaska's population are Alaskan Natives, living mostly in small, isolated communities scattered along coastal regions and rivers.[12] The traditional subsistence lifestyle of these communities is being threatened by the changing climate.[13] Although over the past fifty years improved living conditions, safe water and sewage disposal, increases in community-health providers, and an integrated community health care system have led to an increase in life expectancy in these Native populations, the health and life expectancy of these populations still lags behind non-indigenous residents of Alaska.[14] As the population densities increase in this region over time, the need for proper sanitation and clean water becomes critical.[15]

The melting permafrost, flooding, and storm surges are progressively destroying village sanitation and drinking water infrastructures in many of these communities, paving the way for waterborne diseases such as *Giardia* and *Cryptosporidium* to disseminate throughout these communities.[16] Arctic surface waters, including streams, rivers, lakes, and tundra ponds, are at a greater risk of contamination by pathogens than groundwater supplies, and often require treatment to ensure the water is safe for consumption.[17] However, contaminants can exist in both surface and groundwater, and must be removed early in the water treatment process to provide safe water for drinking.[18]

Clean water scarcity could also increase, as flooding may limit the availability of clean, fresh water, and force people towards contaminated water sources.[19] Salt water intrusion from rising sea levels, and irrigation-and drainage system flooding following changes in precipitation, could lead to an increase in the rate of outbreak of waterborne diseases such as *Giardia* and *Cryptosporidium*.[20] In areas with poor sanitation systems, or rural areas that have previously relied on fresh water sources, flooding and rising sea

12. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 474 (2008).

13. Allen J. Parkinson, *The International Polar Year, 2007-2008, An Opportunity to Focus on Infectious Diseases in Arctic Regions*, 14 EMERG. INFECT. DISEASES 1, 2 (2008).

14. *Id.*

15. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 488 (2005).

16. Allen J. Parkinson, *The International Polar Year, 2007-2008, An Opportunity to Focus on Infectious Diseases in Arctic Regions*, 14 EMERG. INFECT. DISEASES 1, 2 (2008).

17. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 490 (2005).

18. *Id.*

19. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 85-86 (World Health Organization) (2003).

20. *Id.* at 86.

levels could create an optimal environment for waterborne infectious diseases.[21]

The devastation of communities by flooding or severe storms can be followed by the spread of waterborne disease[22], such as *Cryptosporidium* and *Giardia*, which are carried in untreated water. Sanitation systems provide high-quality and adequate quantities of water, offering populations protection against waterborne diseases.[23] However, in Alaska's remote, rural communities, inadequate sanitation systems account for a large percentage of illnesses, such as hepatitis A.[24]

Alaska has seen many recent flooding events as the climate has begun to warm. In 2000, a storm surge spread sewage lagoon waste through Kipnuk in 2004; a saline intrusion occurred after a storm surge in Nunam Iqua; in 2005, community water sources disappeared in Kwigillingok, and flooding of Juneau's septic systems occurred.[25]

Climate Change

The earth's climate is changing because of human activities which are altering the chemical composition of the atmosphere through the buildup of greenhouse gases.[26] As the buildup of greenhouse gases continues, global warming will begin to change temperatures throughout the world, making some places drier, others wetter, and creating more intense, short bursts of precipitation that could lead to flooding.[27]

Coastal zones are often affected adversely by temperature and precipitation extremes.[28] Coastal areas may see sea levels rise 0.12 inches per year

21. *Id*. at 86-87.

22. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 488 (2005).

23. *Id*. at 489.

24. *Id*.

25. Michael J. Beach, Associate Director for Healthy Water National Center Zoonotic, Vector-borne, and Enteric Disease, Centers for Disease Control and Prevention, *The changing epidemiology of waterborne disease outbreaks in the United States: Implications for further system infrastructure and future planning* (2008), http://www.iom.edu/Object.File/Master/59/280/Beach.pdf.

26. Environmental Protection Agency, *Climate Change and Alaska*, EPA 236-F-98-007b, Sept. 1998, http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BMRWA/$File/ak_impct.pdf.

27. *Id*.

28. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 146 (World Health Organization) (2003).

alone due to melting ice.[29] Runoff in Alaska varies widely, depending on location and elevation, but largely results from late spring and summer melting of snow and glacial ice.[30] At lower elevations, late summer rains contribute to runoff.[31] At higher latitudes and elevations, increases in precipitation could lead to greater snowfall and snow accumulation.[32] In other regions, warmer winters could lead to less winter precipitation as snow and more as rainfall.[33] Warmer temperatures could mean earlier, more rapid snowmelts and earlier ice breakups.[34] These events could cause severe flooding, and earlier ice breakups could erode the beaches and coastal areas, increasing coastal vulnerability to flooding.[35]

As the climate continues to warm, sea levels will also rise, and salt water will intrude into freshwater areas, creating declines in water quantity and quality.[36] As the frequency of extreme weather events such as flooding and rising sea levels will increase, previously used fresh water sources will begin to see saltwater and sewage intrusions, putting local water supplies under increased stress.[37] Climate change impacts water resources and sanitation by reducing or increasing water supply to such a degree that local sanitation systems are incapable of keeping up with the flow of the water.[38] Attempts at water management are opposed by a growth in demand for water, climate change, water availability, and the nearly-impossible ability to quantify sanitation and hygiene requirements.[39]

Climate change can also impact water sources by limiting restoration for groundwater due to drought or intense but infrequent rainstorms resulting in water lost to runoff; reduction of surface water available due to drought or intense storms which would cause water to release too rapidly; contamination of coastal groundwater and surface water supplies due to sea

29. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 471 (2008).

30. Environmental Protection Agency, *Climate Change and Alaska*, EPA 236-F-98-007b, Sept. 1998, http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BMRWA/$File/ak_impct.pdf.

31. *Id.*

32. *Id.*

33. *Id.*

34. *Id.*

35. *Id.*

36. Magdalena A.K. Muir, *Ocean and Fisheries Law: Ocean and Climate Change: Global and Arctic Perspectives*, 7 SUSTAINABLE DEV. L. & POL'Y 50, 50 (2006).

37. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 146 (World Health Organization) (2003).

38. *Id.* at 96.

39. *Id.*

level rise and sea water intrusion; damage to water supply structural mechanisms from severe storms; and surface water contamination by wildlife extending their range farther north, such as the beaver changing course of streams and introducing *Giardia* to surface water supplies.[40] Water treatment systems are vulnerable to damage by climate change as source water is contaminated through storm runoff, sea water intrusion, and turbidity in water sources following a storm.[41]

Waterborne Parasitic Protozoan Diseases: *Giardia* and *Cryptosporidium*

The most common enteric parasitic infections in the United States are caused by *Cryptosporidium parvum* ("*Cryptosporidium*") and *Giardia lamblia* ("*Giardia*").[42] These waterborne pathogens are characterized by a low infectious dose, good survival in a cold water environment, and resistance to water treatment practices that were once state of the art.[43]

Cryptosporidium are microbial parasites that cause diarrheal disease.[44] *Cryptosporidium* live in the intestine of infected humans or animals, and are spread through soil, food, water, or surfaces that have been contaminated with the feces of infected humans or animals.[45] While watery diarrhea is the most common symptom of *Cryptosporidium*, other symptoms include stomach cramps or pain, dehydration, nausea, vomiting, and fever.[46] Symptoms appear two to ten days after a person becomes infected with the parasite, and can last one to two weeks.[47] A *Cryptosporidium* infection is very contagious, but with proper treatment using nitazoxanide or allowing symptoms to run their natural course, a *Cryptosporidium* infection can be cured.[48]

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40. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 491 (2005).

41. *Id.*

42. Lee-Ann Jaykus, *Epidemiology and Detection as Options for Control of Viral and Parasitic Foodborne Disease*, 3 EMERG. INFECT. DISEASES 529, 531 (1997).

43. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4 (Suppl. 2) J. WATER HEALTH, 19, 27 (2006).

44. Centers for Disease Control, Division of Parasitic Diseases, *Cryptosporidium Infection –General Public: Fact Sheet for the general public*, http://www.cdc.gov/Cryptosporidium/factsheets/infect.html.

45. *Id.*

46. *Id.*

47. *Id.*

48. *Id.*

Giardia is a microscopic parasite that causes diarrhea illness.[49] The *Giardia* parasite lives in the intestine of infected animals or humans and is passed by feces.[50] The parasite is protected by an outer sheath, which allows it to survive outside the body and in the environment for months.[51] *Giardia* is found on surfaces or in soil, food, or water that has been contaminated with the feces of infected humans or animals.[52] Symptoms include diarrhea, gas, greasy stools, abdominal or stomach cramps, upset stomach or nausea, and can occur one to two weeks after infection and last two to six weeks.[53] Although there are many prescription drugs to treat *Giardia* effectively, *Giardia* is very contagious.[54]

Cryptosporidium and *Giardia* enter water as excreted dormant cysts or oocytes by an animal,[55] and are usually present in such low concentrations that detection is nearly impossible.[56] In fact, in order to detect these parasitic pathogens in contaminated water, a very large water sample, between 100 and 1000 liters, must be taken and concentrated before detection is possible.[57] *Cryptosporidium* oocytes are so small, approximately five microns, and are so difficult to remove from water, that in one study, *Cryptosporidium* oocytes were found in finished water, indicating some passage of the parasite from source to treated drinking water.[58] Contaminated water can be treated to prevent *Giardia* infection by either boiling the water or using a filter rated for cyst removal.[59] If the water cannot be treated for *Giardia* removal through

49. Centers for Disease Control, Division of Parasitic Diseases, *Giardia Infection—Giardiasis: Fact Sheet for the general public*, http://www.cdc.gov/ncidod/dpd/parasites/*Giardia*sis/factsht_*Giardia*.htm.

50. *Id.*

51. *Id.*

52. *Id.*

53. *Id.*

54. *Id.*

55. Cindy Christian, Field Operations and Implementation Manager, ADEC Drinking Water Program, *Waterborne Diseases: Meeting the Drinking Water Challenge*, http://www.dec.state.ak.us/eh/docs/dw/training/i.pdf.

56. Lee-Ann Jaykus, *Epidemiology and Detection as Options for Control of Viral and Parasitic Foodborne Disease*, 3 EMERG. INFECT. DISEASES 529, 533 (1997).

57. *Id.*

58. Frank C. Curriero, *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1948-1994, 91 AM. J. PUBLIC HEALTH 1194, 1198 (2001).

59. Centers for Disease Control, Division of Parasitic Diseases, *Giardia Infection—Giardiasis: Fact Sheet for the general public*, http:// www.cdc.gov/ncidod/dpd/parasites/*Giardia*sis/factsht_*Giardia*.htm.

either of those ways, chlorination or iodination can be used, though they may be less successful.[60]

Climate change is expected to have a substantial influence on spatial and temporal distribution of host-pathogens and the emergence of disease conditions in North America.[61] Climate change and the resulting ecological changes, such as changes in temperature, will drive the introduction, dissemination, and emergence of pathogens by altering geographic distributions and host associations of pathogens such as *Giardia* and *Cryptosporidium*.[62]

As the climate changes, these pathogens may experience a decrease in incubation period and differential shifts in replication, an extension in seasonal windows and transmission dynamics, host-mediated shifts in geographic distribution, and changes in the timing and persistence of outbreaks.[63'64] In coastal waters, such as those in Alaska, pathogens may proliferate under ideal conditions of increased sunlight and surface temperatures, sewage runoff contamination, and sea temperature.[65] There are multiple routes of water contamination by fecal-oral diseases such as *Giardia* and *Cryptosporidium*, and climate change will only increase the possibility of contamination.[66]

As the climate changes, the habitat, distribution, and seasonal patterns for many pathogen host species are changing.[67] For instance, the beaver, the common mammalian *Giardia* host in the Arctic, is moving northward as the climate changes and its habitat and vegetation sources spread northward.[68,69] As the beaver moves northward, *Giardia* infections may begin to occur in regions where they were previously unknown, as drinking water in

60. *Id*.

61. E.P. Hoberg et al., *Pathogens of domestic and free-ranging ungulates: global climate change in temperate to boreal latitudes across North America*, 27 REV. SCI. TECH. OFF. INT'L EPIZ. 511, 515 (2008).

62. *Id*. at 511.

63. *Id*. at 516.

64. Allen J. Parkinson et al., *Potential Impact of Climate Change on Infectious Disease in the Arctic*, 64 INT'L J. CIRCUMPOLAR HEALTH 478, 478 (2005).

65. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 474 (2008).

66. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 85 (World Health Organization) (2003).

67. Michael J. Bradley et al, *The Potential Impact of Climate Change on Infectious Diseases of Arctic Fauna*, 64 INT'L J. CIRCUMPOLAR HEALTH 468, 471 (2005).

68. Allen J. Parkinson et al., *Potential Impact of Climate Change on Infectious Disease in the Arctic*, 64 INT'L J. CIRCUMPOLAR HEALTH 478, 481 (2005).

69. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 Am. J. Prev. Med. 468, 475 (2008).

the rural Arctic areas often comes from surface water, and surface water can be contaminated by beaver feces carrying *Giardia*.[70]

Because *Cryptosporidium* and *Giardia* are waterborne, they can spread easily by contamination of a drinking or recreational water source; ingestion of seafood from contaminated water or fresh produce irrigated with contaminated water; or from a flood, drought, or storm, which may bring contaminated water to vast land areas.[71] Runoff from rain or flood water may drain directly into ground wells used for drinking water and contaminate the well water.[72] Large community-wide waterborne outbreaks of parasitic protozoa are usually associated with surface water supplies that are either unfiltered or inadequately filtered.[73] Contamination of the distribution system has become increasingly important as a cause of waterborne disease outbreaks.[74] Higher ambient temperatures in the Arctic may increase the incidences of flooding, which may result in outbreaks of waterborne infection, such as *Giardia or Cryptosporidium*.[75] Rainfalls will be heavier, triggering sewage overflows, contaminating drinking water and most likely leading to an increased risk of waterborne disease outbreaks.[76,77] In a 2001 study commissioned by the EPA, heavy rainfall was correlated with more than half of the United States' outbreaks of waterborne illness from 1948 to 1994.[78]

International and Federal Law: Waterborne Disease and Drinking Water

The International Health Regulations ("IHR") are the only binding, international agreement on communicable diseases between World Health

70. Allen J. Parkinson et al., *Potential Impact of Climate Change on Infectious Disease in the Arctic*, 64 INT'L J. CIRCUMPOLAR HEALTH 478, 481 (2005).

71. *Id*. at 479.

72. Centers for Disease Control, Division of Parasitic Diseases, *Giardia Infection—Giardiasis: Fact Sheet for the general public*, http:// www.cdc.gov/ncidod/dpd/ parasites/Giardiasis/factsht_Giardia.htm.

73. Lee-Ann Jaykus, *Epidemiology and Detection as Options for Control of Viral and Parasitic Foodborne Disease*, 3 EMERG. INFECT. DISEASES 529, 530 (1997).

74. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4(Suppl. 2) J. WATER HEALTH, 19, 28 (2006).

75. Allen J. Parkinson et al., *Potential Impact of Climate Change on Infectious Disease in the Arctic*, 64 INT'L J. CIRCUMPOLAR HEALTH 478, 478 and 481 (2005).

76. Kari Lydersen, *Risk of Disease Rises with Water Temperatures*, WASH. POST, Oct. 20, 2008, at A08.

77. Magdalena A.K. Muir, *Ocean and Fisheries Law: Ocean and Climate Change: Global and Arctic Perspectives*, 7 Sustainable Dev. L. & Pol'y 50, 51 (2006).

78. Kari Lydersen, *Risk of Disease Rises with Water Temperatures*, WASH. POST, Oct. 20, 2008, at A08.

Organization ("WHO") members.[79] The IHR provide an international, unified code on infectious disease control.[80] The IHR is kept up to date regarding scientific advances through Article 22, which provides that all amendments are binding on member states unless the member state notifies the WHO director-general of a rejection or reservations within a certain time period.[81] Provisions are also subject to approval by the World Health Authority (WHA).[82] However, the promise of the WHO for infectious disease control through effective use of international law has not been fulfilled.[83] The WHO has been reluctant to use international law to advance initiatives on world health, instead using non-binding recommendations under Article 23 of the WHO Constitution.[84]

The IHR utilize a global surveillance system for diseases subject to the IHR, requiring certain types of health-related capabilities at member states' ports of entry, and also setting out disease-specific provisions.[85] However, the IHR have not been effective.[86] Member states regularly fail to notify the WHO of IHR-regulated diseases, and the IHR currently only apply to three diseases.[87] To increase effectiveness, reporting must be expanded to include syndrome reporting, there must be greater information flow, and the IHR must be expanded to include emerging infectious diseases.[88]

Water pollution and water-related diseases affect one billion people around the world who lack safe drinking water, and two billion people who lack adequate sanitary facilities.[89] Local water pollution is the greatest threat, but transnational waterways can bring diseases and raw sewage from one state to another.[90] Marine pollution is mostly derived from land-based sources such as human contamination and human sewage.[91] Generally, international law provides that States cannot intentionally pollute transboundary waters, but States are responsible for their own water sources.[92] How-

79. David P. Fidler, *International Law and Infectious Diseases*, 58 (1999).
80. *Id.*
81. *Id.* at 59.
82. *Id.*
83. *Id.* at 60.
84. *Id.* at 61.
85. *Id.*
86. *Id.* at 65.
87. *Id.*
88. *Id.* at 65-68.
89. *Id.* at 247.
90. *Id.* at 248.
91. *Id.*
92. *Id.* at 259.

ever, State responsibilities with regards to transnational waterways are complicated, because besides preventing intentional pollution of transnational waterways, there is very little international law regarding State-specific use of transnational water for local drinking and other use.[93]

Local water pollution poses an indirect threat because outbreaks of waterborne diseases may spread through the transnational waterways from State to State.[94] Land-based pollution, such as sewage runoff and vessel-source pollution, accounts for the majority of marine water pollution.[95] However, beyond regional treaties or general marine safety treaties, there is not much international law for worldwide regulation of waterborne infectious diseases.[96]

Most emerging infectious diseases are caused by changes in "microbial traffic" – that is, the introduction and dissemination of existing agents into human populations either from other species, or from other, smaller human populations.[97] Environmental change is a major cause of such microbial traffic changes, and active-control public-health programs have been shown to be successful at stopping such traffic changes in diseases such as cholera.[98]

The U.S.-based Federation of American Scientists' Program for Monitoring Emerging Diseases (ProMED), sponsored by the WHO, facilitates worldwide electronic data exchange on infectious diseases, providing instantaneous linkage between field scientists in countries around the world.[99] There are also other international networks, such as the WHO Global Influenza Surveillance Network, the International Clinical Epidemiology Network, and the International Office of Epizootics Worldwide Information Systems, and international research facilities working on global monitoring and surveillance networks for emerging infectious diseases.[100]

Another international effort to provide safe drinking water is the International Circumpolar Surveillance System (ICSS), which is an effort between Arctic countries and includes an integrated network of hospital and public health facilities to monitor infectious diseases of concern.[101] Originally, the

93. *Id*. at 260.

94. *Id*. at 260-261.

95. *Id*. at 261.

96. *Id*. at 261-264.

97. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 190 (World Health Organization) (2003).

98. *Id*.

99. *Id*.

100. *Id*.

101. Center for Disease Control, Arctic Investigations Program, http://www.cdc.gov/ncidod/aip (last visited November 16, 2009).

ICSS was a surveillance system used to monitor and prevent S*treptococcus pneumoniae* outbreaks.[102] The CDC has also set up the Arctic Investigations Program (AIP) under the National Center for Infectious Diseases.[103] The AIP conducts many research projects, including continual surveillance of some known infectious diseases, including S*treptococcus* and hepatitis.[104]

The U.S. response to provide and protect safe drinking water is the Federal Safe Drinking Water Act (SDWA), which was amended in 1996 to ensure that the public water supply systems meet national standards to protect public health.[105, 106] The SDWA was designed to regulate contaminants in drinking water supplied by public water systems, and establishes a program for the protection of underground sources of drinking water.[107] The Act requires the Environmental Protection Agency (EPA) Administrator to set, monitor and disseminate national drinking water standards specifying dangerous contaminants, including physical, chemical and biological contaminants, and prescribing a maximum contaminant level or satisfactory treatment techniques.[108, 109] The EPA is required to consult with the scientific community and periodically publish a list of potentially hazardous diseases and contaminants.[110]

A public water system is defined by the SDWA as "a system for the provision to the public of water for human consumption, through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals."[111] It has been argued that the SDWA is an unconstitutional legislative use of the Commerce Power, imposing a one-size-fits-all regulation for a national system of drinking water regulation.[112] Although most states have adopted drinking water regulations that meet SDWA's minimum requirements, the Public Water Sys-

102. *Id.*

103. Arctic Investigations Program, http://www.cdc.gov/ncidod/aip/research/ics.html (last visited January 6, 2009).

104. *Id.*

105. 42 U.S.C.A. §§ 300(f) *et seq.* (2008).

106. Lawrence O. Gostin, *Water Quality Laws and Waterborne Diseases:* Cryptosporidium *and Other Emerging Pathogens*, 90 AM. J. PUBLIC HEALTH 847 (2000).

107. 78 Am. Jur. 2d *Waterworks and Water Companies* §42 (2008).

108. *Id.*

109. Lawrence O. Gostin, *Water Quality Laws and Waterborne Diseases:* Cryptosporidium *and Other Emerging Pathogens*, 90 AM. J. PUBLIC HEALTH 847, 848 (2000).

110. 78 Am. Jur. 2d *Waterworks and Water Companies* §42 (2008).

111. 42 U.S.C.A. §§ 300(f) *et.seq.* (2008).

112. Garrett W. Johnson, *Constitutional Limits to Federal Environmental Regulation: The Commerce Clause Challenge to the Safe Drinking Water Act*, 10 QUINNIPIAC HEALTH L.J. 77, 78 (2006).

tems (PWSs) are subject to state regulations rather than to the SDWA itself.[113] However, states are required to adopt standards as stringent as those adopted by the EPA, and the failure to do so can lead to an EPA take over as the primary enforcer of the SDWA. [114] Only one state, Louisiana, currently has requirements that exceed federal testing or filtration requirements.[115]

The U.S. Waterborne Disease and Outbreak Surveillance System (WBDOSS) is the primary source of data concerning the scope and effects of waterborne-disease and outbreaks in the United States.[116] WBDOSS is conducted to characterize the epidemiology and etiology of waterborne disease and outbreaks (WBDOs)and identify important waterborne pathogens and water system deficiencies; improve detection and investigation capabilities; and collaborate with local, state, federal, and international agencies on initiatives to prevent waterborne disease.[117] However, WBDOSS is passive, and reporting is voluntary.[118] Many factors influence whether a waterborne outbreak is recognized and investigated, including public awareness, availability of local testing, and resources available to local health departments for surveillance and investigation.[119]

National drinking water regulations have had a positive impact on waterborne disease outbreaks; however, unregulated deficiencies outside the jurisdiction of a water utility remain a problem.[120] In order to trigger identification of an outbreak, epidemiologic evidence must point to a drinking water source from which two or more persons became ill at similar times.[121]

113. *Id.* at 84.

114. Lawrence O. Gostin, *Water Quality Laws and Waterborne Diseases: Cryptosporidium and Other Emerging Pathogens*, 90 AM. J. PUBLIC HEALTH 847, 849 (2000).

115. *Id.* at 842.

116. Michael J. Beach, Associate Director for Healthy Water National Center Zoonotic, Vector-borne, and Enteric Disease, Centers for Disease Control and Prevention, *The changing epidemiology of waterborne disease outbreaks in the United States: Implications for further system infrastructure and future planning* (2008), http://www.iom.edu/Object.File/Master/59/280/Beach.pdf.

117. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4 (Suppl. 2) J. WATER HEALTH, 19, 19 (2006).

118. *Id.* at 21.

119. *Id.*

120. Michael J. Beach, Associate Director for Healthy Water National Center Zoonotic, Vector-borne, and Enteric Disease, Centers for Disease Control and Prevention, *The changing epidemiology of waterborne disease outbreaks in the United States: Implications for further system infrastructure and future planning* (2008), http://www.iom.edu/Object.File/Master/59/280/Beach.pdf.

121. Yvonne Andersson & Patrick Bohan, *Water Quality: Guidelines, Standards and Health* 122 (Loma Fewtrell & Jamie Bartram. Eds., World Health Organization, 2001).

Outbreaks caused by water or ice contamination are not classified as WBDOs.[122] There is no national surveillance system in place for WBDOs, and all the data gathered by WBDOSS is voluntarily reported to the CDC.[123]

Of the 548 WBDOs between 1948 and 1994, 24% were from surface water contamination, 36% were from groundwater contamination, and 40% had an unknown water contamination source.[124] Between 1991 and 2002, 16% of waterborne outbreaks were caused by *Giardia*, and 7% were caused by *Cryptosporidium*.[125] In one flood plain in Pennsylvania that was tested, 64% of farms tested positive for *Cryptosporidium*.[126] The high percentage of *Cryptosporidium*-positive farms may result from the fact that *Cryptosporidium* is shed in high numbers of infectious oocytes dispersed in mammalian feces and is highly prevalent in ruminants.[127]

Since 1991, no WBDOs have been associated with untreated surface water systems, largely due to EPA rules and regulations that require the adequate treatment of public water systems using surface water.[128] However, municipal water systems, overburdened by extreme rainfall events or snowmelt, discharge the excess wastewater directly into surface water bodies, contaminating the surface water with *Cryptosporidium*, *Giardia*, and other waterborne pathogens.[129]

In 1993, following torrential rains, a *Cryptosporidium* outbreak in Milwaukee, Wisconsin, was responsible for 54 deaths, with 403,000 people exposed to *Cryptosporidium*.[130] The outbreak was caused by raw sewage being sucked back into water supplies, and because *Cryptosporidium* is not sensitive to chlorine, it escaped water treatment.[131] Although the U.S. has a strong

122. *Id.*

123. *Id.*

124. Frank C. Curriero, *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1948-1994, AM. J. PUBLIC HEALTH 1194, 1196 (2001).

125. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4 (Suppl. 2) J. WATER HEALTH, 19, 26 (2006).

126. Frank C. Curriero, *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1948-1994, 91 AM. J. PUBLIC HEALTH 1194, 1198 (2001).

127. *Id.*

128. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4 (Suppl. 2) J. WATER HEALTH, 19, 24 (2006).

129. Frank C. Curriero, *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1948-1994, 91 AM. J. PUBLIC HEALTH 1194, 1198 (2001).

130. Kari Lydersen, Risk of Disease Rises with Water Temperatures, WASH. POST, October 20, 2008, at A08.

131. *Id.*

public health infrastructure, major overhauls are still needed to deal with increasing amounts of runoff from downpours and flooding as the climate continues to change.[132]

Twenty-one percent of waterborne disease outbreaks in the United States from 1991-2000 are from parasitic protozoa.[133] In Alaska, from 2000-2005, an average of one *Cryptosporidium* and ninety-six *Giardia* outbreaks per year were reported.[134] In a case study of ten surface water areas on the North Slope in Alaska, the highest levels of *Giardia* were found immediately after the spring thaw, and the highest levels of *Cryptosporidium* were found when the ice cover returned in the fall.[135]

Current Alaska Water Supply Infrastructure

Water systems include a water source, storage facility, and distribution system.[136] Water sources contaminated by biological constituents require treatment to render the supply safe for human consumption.[137] In the United States, contaminated drinking water causes close to a million people a year to fall ill and up to 900 to die annually.[138]

Groundwater is the water below the earth's surface that fills the spaces between soil particles or rocks.[139] Water moving from the surface through an unsaturated zone, containing both air and water in the cracks and spaces, to the deeper saturated zone, containing only water in the cracks and spaces, replenish and recharge the aquifer, which occurs when enough groundwater is present to provide an economically viable water supply.[140]

Groundwater supplies about 35% of urban drinking water, and close to 95% of rural drinking water.[141] Groundwater is readily accessible and generally remains useable without treatment.[142] However, in areas of significant

132. *Id.*

133. Cindy Christian, Field Operations and Implementation Manager, ADEC Drinking Water Program, *Waterborne Diseases: Meeting the Drinking Water Challenge*, http://www.dec.state.ak.us/eh/docs/dw/training/i.pdf.

134. *Id.*

135. *Id.*

136. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 490 (2005).

137. *Id.*

138. *Id.*

139. Sally Benjamin and David Belluck, *State Groundwater Regulation: Guide to Laws, Standards, and Risk Assessment*, 8 (1994).

140. *Id.*

141. *Id.* at 9.

142. *Id.* at xv.

human habitation and activity, groundwater is often contaminated.[143] There is no single federal law or program directly and comprehensively addressing the pollution of groundwater, as there is for surface water.[144] Instead, the federal government has passed most of the responsibilities for groundwater protection to state governments.[145] The SDWA and its 1986 amendments provide for regulation and protection of groundwater through the use of public drinking water supply standards.[146]

Under Title 18, Section 70.020 of the Alaska Administrative Code, four of the designated uses of groundwater are: (1) freshwater supply—drinking, culinary, and food processing; (2) freshwater supply—agriculture, including irrigation and stock watering; (3) freshwater supply—aquaculture; and (4) freshwater supply—industrial.[147] Groundwater is used as drinking water by the majority of rural and urban Alaskans.[148] In 1994, 85% of the state's public drinking water supply systems, serving over 60% of the state population, were using groundwater.[149] The majority of single-family homes in Alaska obtain their water from private wells.[150] Major threats to Alaska's groundwater include wastewater disposal, solid waste facilities, and saltwater intrusion.[151]

The Alaskan Department of Environmental Conservation (ADEC), Division of Environmental Health, Drinking Water Program requires PWSs be in compliance with the state drinking water regulations, in accordance with the Federal Safe Drinking Water Act and Amendments.[152] A PWS supplies water to consumers and is not a private water system.[153] Current Alaskan drinking water regulations set the standards for safe drinking water and regulate drinking water contaminants, including parasitic protozoans and the level of those contaminants allowed in the water.[154] In establishing a new surface water source, officials take into consideration the water source's history and

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143. *Id*.

144. *Id*. at 9.

145. *Id*. at xv.

146. *Id*. at 21.

147. 18 A.A.C. 70.020 (Lexis 2009; Updated through Register 191, October 2009).

148. Benjamin and Belluck, *supra*, n139, at 113.

149. *Id*.

150. *Id*.

151. *Id*.

152. Cindy Christian, Field Operations and Implementation Manager, ADEC Drinking Water Program, *Waterborne Diseases: Meeting the Drinking Water Challenge*, http://www.dec.state.ak.us/eh/docs/dw/training/i.pdf (Last Visited, February 2009).

153. *Id*.

154. *Id*.

current conditions, including the history of waterborne disease outbreaks, if any, and whether the system using a groundwater source has experienced a waterborne disease outbreak directly related to the water source.[155]

In Alaska currently, water filtration is required for *Giardia* in "community" water systems, "non-transient non-community" water systems, and "transient non-community" water systems with a surface or ground water source.[156] Water treatment must consistently achieve at least 99.9% "removal, inactivation, or a combination of removal and inactivation of *Giardia lamblia* cysts between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream of treatment and before or at the first customer."[157]

If an Alaska community or transient or non-transient non-community water system does not provide filtration, disinfection treatment must still be sufficient to ensure at least 99.9% inactivation of *Giardia cysts*.[158] *Giardia* cysts can be inactivated by free chlorine at 0 to 25 degrees Celsius, or with carbon dioxide, ozone, or chloramine.[159] ADEC will assess the effectiveness of the removal or inactivation of *Giardia* cysts in accordance with standard sanitary engineering practices and principles.[160] A recorded log must show a minimum of 0.5 log *Giardia* cyst inactivation to supplement filtration and shall maintain a second treatment barrier for microorganisms.[161] If a waterborne disease outbreak occurs, additional disinfection and monitoring or evidence of the reliability of current treatment techniques may be deemed necessary by the EPA or the ADEC.[162] In 2008, a ballot initiative entitled "Alaska Clean Water Act" focused on minerals from mine runoff such as cyanide and sulfuric acid, but did not address microbial contamination of water.[163]

In the Alaskan Arctic, sanitation facilities have varying levels of service. In the most basic systems, water and waste are hauled to and from residences by hand.[164] Community water and wastewater haul systems provide a greater amount of water for sanitation purposes, and piped utility systems

155. Alaska Admin. Code tit.18, § 80.600 (2008).

156. *Id*. at § 80.010.

157. *Id*.

158. *Id*. at § 80.635.

159. *Id*. at § 80.010 and § 80.635.

160. *Id*. at § 80.635.

161. *Id*. at § 80.635

162. *Id*.

163. Alaska Clean Water Initiative 2008, http://www.renewableresources coalition.org/Clean_Water_Initiative_1.pdf (last visited March 14, 2009).

164. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 489 (2005).

provide communities with the highest level of service.[165] However, piped utility, the above- or below-ground supports for the pipeline, and the pipeline itself, are vulnerable to contamination as well.[166] In the Arctic, water pipes continuously circulate water for freeze protection.[167] If there is a freeze in the pipe, the water pipe can burst, leading to a contamination of the water within the pipe.[168] Flooding, melting permafrost, and erosion can also damage the piping system, in particular, the actual water pipes and the supports above and below ground that the pipes rely on.[169]

Many of the effects of climate change on water distribution systems also apply to wastewater collection infrastructure.[170] Wastewater systems collect human waste and provide treatment and ultimately disposal of the waste.[171] However, improper methods of collecting, treating, or disposing of human waste can result in an outbreak of disease.[172] In Alaska during the years 1972- 95, more than 7000 cases of hepatitis A, another fecal-oral transmitted disease, were reported to the state health department.[173] Inadequate sewage disposal was cited as the cause of the outbreaks.[174]

The level of wastewater collection service in Alaska varies. As communities grow farther apart from the urban centers towards the rural areas, sanitation facilities decrease in frequency and level of service.[175] Holding tanks have been used when piped systems are unavailable, and provide an improved level of service over the commonly found method of small buckets used for collection found in rural Alaskan communities.[176] Piped utilities remain the best method for sanitation and provide the highest level of service; however, many rural northern Alaskan communities do not have such systems.[177] Failed collection systems can discharge human waste into the environment, contaminating water supplies and increasing the transmission of disease.[178]

165. *Id.* at 489.
166. *Id.* at 491.
167. *Id.*
168. *Id.*
169. *Id.* at 492.
170. *Id.* at 493.
171. *Id.* at 492.
172. *Id.*
173. *Id.*
174. *Id.*
175. *Id.*
176. *Id.*
177. *Id.*
178. *Id.* at 493.

In the small, remote communities of the Arctic, wastewater treatment is generally limited to simple systems, as mechanical systems are prohibitively expensive to build and operate.[179] Individual wastewater treatment facilities in these communities, such as outhouses and septic systems, and communal facilities such as earthen lagoons, tundra ponds, and septic tanks with ocean outfalls or drainfields, can be affected by climate change, in particular flooding, erosion leading to loss of structural support, storm surges, and sea water intrusion.[180] Additionally, access routes for collection and disposal, as well as landfill areas, can become damaged or destroyed in storm surges, flooding, or erosion, leading to the spread of contaminated waste and wastewater throughout the community.[181]

Proposed Solutions for Rural Alaskan Waterborne Disease Vulnerability

In order to successfully reduce the impact of climate change on rural communities, Alaska must protect source water, both surface and groundwater, create a more advanced water supply infrastructure for rural areas, and increase community public health education in rural areas. If Alaska does not proactively take preventative measures, there is a serious risk of the rural population, one-sixth of Alaska's total population,[182] being decimated.

International and U.S. strategies for preventing waterborne disease outbreaks center around the idea of monitoring and surveillance. The WHO has focused on advancing world health initiatives through non-binding international laws.[183] The IHR uses a global surveillance system, focusing on a limited subset of infectious diseases at specific locations in countries, such as at ports of call, but this system has been of very limited success.[184] International law protects transnational waterways from intentional contamination,[185] but globally, there is currently very little beyond regional treaties and general maritime safety treaties that regulates waterborne infectious diseases.[186] Other scientific efforts, such as ProMED[187] and the ICSS,[188] create an

179. *Id.*

180. *Id.*

181. *Id.* at 494.

182. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 474 (2008).

183. David P. Fidler, *International Law and Infectious Diseases*, 60-61 (1999).

184. *Id.* at 61.

185. *Id.* at 259.

186. *Id.* at 261-264.

187. Anthony J. McMichael et al., *Climate Change and Human Health: Risks and Responses* 201 (World Health Organization) (2003).

integrated network of scientists around the globe to monitor and provide surveillance of the spread of infectious diseases, but provide little in the way of preventative measures.

U.S. strategies to prevent the spread of waterborne infectious diseases mainly focus on the SDWA, ensuring the safety of drinking water through treatment mechanisms[189] and the monitoring and surveillance of waterborne infectious disease outbreaks through WBDOSS.[190] First, the SDWA ensures PWSs meet national standards, but only protects those water supply systems "on the grid" and may not extend protection to rural areas where the system serves less than twenty-five individuals.[191] Second, the SDWA regulates the adequate treatment of public water systems using surface water, not systems using groundwater.[192] Third, extreme rainfall events, snowmelt, or flooding often can overwhelm a public water supply or sanitation system, and overflow from these systems is unregulated.[193] Fourth, although Alaska faces unique challenges of water source contamination, only one other state has adopted drinking water standards that exceed those of the SDWA.[194] Fifth, although the WBDOSS is in place, it is a voluntary reporting system, and no U.S. national surveillance and mandatory reporting system is in place for waterborne disease outbreaks.[195]

Alaska faces unique challenges that are not well served by a simple surveillance and monitoring system, or by current regulations. Current

188. Arctic Investigations Program, http://www.cdc.gov/ncidod/aip/research/ics.html (last visited January 6, 2009).

189. Lawrence O. Gostin, *Water Quality Laws and Waterborne Diseases: Cryptosporidium and Other Emerging Pathogens*, 90 AM. J. PUBLIC HEALTH 847, 847 (2000).

190. Michael J. Beach, Associate Director for Healthy Water National Center Zoonotic, Vector-borne, and Enteric Disease, Centers for Disease Control and Prevention, *The changing epidemiology of waterborne disease outbreaks in the United States: Implications for further system infrastructure and future planning* (2008), http://www.iom.edu/Object.File/Master/59/280/Beach.pdf.

191. 42 U.S.C.A. §§ 300(f) *et seq*. (2008).

192. Michael F. Craun et al., *Waterborne outbreaks reported in the United States*, 4 (Suppl. 2) J. WATER HEALTH, 19, 24 (2006); Sally Benjamin and David Belluck, 9 (1994).

193. Frank C. Curriero, *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1948-1994, 91 AM. J. PUBLIC HEALTH 1194, 1198 (2001).

194. Garrett W. Johnson, *Constitutional Limits to Federal Environmental Regulation: The Commerce Clause Challenge to the Safe Drinking Water Act*, 10 QUINNIPIAC HEALTH L.J. 77, 82 (2006).

195. Yvonne Andersson & Patrick Bohan, *Water Quality: Guidelines, Standards and Health* 123 (Loma Fewtrell & Jamie Bartram. Eds., World Health Organization, 2001).

Alaska state drinking water regulations are in compliance with the SDWA,[196] and water treatment requirements for *Giardia* removal from surface or groundwater sources are in place.[197] However, it is unclear whether rural communities, which may not be under Alaska state drinking water regulations because they are not connected to a PWS, have access to safe drinking water. Additionally, wastewater treatment facilities and infrastructure vary greatly between the urban and rural areas of Alaska, and sudden climatic events, such as a flood, might overpower existing water treatment and sanitation facilities, specifically in the rural areas, where such facilities are more primitive.

A surveillance and monitoring system does not proactively prevent waterborne disease outbreaks, but instead serves to stem the tide of a waterborne disease outbreak once an outbreak occurs. However, this sort of system is not feasibly practical for rural areas of Alaska. The Alaskan government must take steps to protect the health of the communities most affected by climate change, including the health impact on the community of a flood, storm, or other natural disaster.[198] The state must provide these rural areas with better infrastructure and resources to cope with the changing climate.[199]

Alaskan rural communities are not always connected with infrastructure to urban areas. Although such infrastructure has improved in the recent years, many rural areas are seasonally cut off from such access. Alaska is not like the lower forty-eight states. In the lower forty-eight states, infrastructure such as highways, airports, and trains connect even the most rural populations to population centers. In Alaska, not all areas are connected with major population centers, and methods of transportation accessibility vary greatly between geographic locations.[200] Air travel is often the best option for reaching remote Alaskan areas, particularly in the Far Northern region.[201] In water-bound communities, ferries are relied upon as the primary link to the outside world.[202] Although there are two main railroads in the

196. Cindy Christian, Field Operations and Implementation Manager, ADEC Drinking Water Program, *Waterborne Diseases: Meeting the Drinking Water Challenge*, http://www.dec.state.ak.us/eh/docs/dw/training/i.pdf.

197. Alaska Admin. Code tit.18, § 80.615 (2008).

198. John A. Warren et al., *Climate Change and Human Health: Infrastructure Impacts to Small Remote Communities in the North*, 64 INT'L J. CIRCUMPOLAR HEALTH 487, 495 (2005).

199. *Id*. at 496.

200. Alaska Department of Transportation, http://www.dot.state.ak.us/ (last visited March 14, 2009).

201. Alaska Air Transportation, http://www.travelalaska.com/Transportation/AroundAir.aspx (last visited March 14, 2009).

202. Alaska Sea Transportation, http://www.travelalaska.com/Transportation/AroundSea.aspx (last visited March 14, 2009).

state, which reach places inaccessible by motor vehicle, the railroads are limited in scope.[203] Although the road network has improved in Alaska over recent decades, it is still subject to Alaska's seasonal weather, and many roads accessible at warmer times of year become inaccessible in the winter season.[204]

With the patchwork transportation network in Alaska, there is a strong possibility that waterborne disease outbreaks caused by climatic events such as flooding could destroy an entire community before an effective response can be requested and mounted. This is part of the reason that Alaska, more than other states, must rely on effective community public health education and water supply infrastructure to support a rural community in times of natural disasters.

If a major climatic event were to occur, such as a flood, the immediate water source for a community could become contaminated by salt water, sewage, and waterborne pathogens. If the community were unaware of the contamination, and did not take additional measures to treat the water, a waterborne disease outbreak could occur quickly. Then, it could possibly take days before notification of the outbreak would reach public health officials, and even longer before a response could be mounted because of the remoteness of the community, and potential for difficulties with means of communication. Meanwhile, pending notification and action by state public health officials, the contaminated water source would continue to be used, possibly infecting the entire community. Repeat this scenario multiple times over a season in various remote communities throughout rural Alaska, and a serious public health emergency emerges. Additionally, if people from these communities, infected with a waterborne pathogen following a climatic disaster, leave the community to seek shelter and refuge from the disaster, the pathogens may be spread into new geographic areas.

To prevent such a disaster, a proactive approach is required. First, Alaska must secure water sources, both surface and groundwater, in rural areas to prevent negative impact and contamination of these sources following a climatic event such as a flood. *Giardia* and *Cryptosporidium* are hard to detect and must be detected early in the treatment process to have the best chance at completely ridding water of the pathogens.[205] To do this, Alaska may need more water infrastructure, such as water treatment facilities and above or underground piping, in rural communities. Another alternative would be to connect rural communities with more suburban and urban

203. Alaska Train Transportation, http://www.travelalaska.com/Transportation/AroundRail.aspx (last visited March 14, 2009).

204. Alaska Road Transportation, http://www.travelalaska.com/Transportation/AroundRoad.aspx (last visited March 14, 2009).

205. Lee-Ann Jaykus, *Epidemiology and Detection as Options for Control of Viral and Parasitic Foodborne Disease*, 3 EMERG. INFECT. DISEASES 529, 533 (1997).

communities through water pipelines, the effect of which would be to provide a clean emergency water supply to rural communities if a climatic event occurs. Although these measures would be costly, they would help to secure Alaska's water sources from flooding, salt water intrusion, and other climatic events.

Second, Alaska must be proactive in community public health education in rural areas against waterborne diseases. With the primitive nature of many of the existing water treatment wastewater facilities, the likelihood of a waterborne disease outbreak remains high. Communities must be educated on waterborne diseases such as *Giardia* and *Cryptosporidium*, including how to prevent and treat contaminated water, and the symptoms of infection by these pathogens. Such education would help by enabling immediate treatment for those infected through contaminated water and avoidance by the community of the contaminated water source, which could potentially save lives and the livelihood of the community.

Conclusion

Climate change has begun to bring many challenges to rural Alaska. Already the beaver population has begun to shift habitat, increasing the chance of surface water source contamination by *Giardia* carried by beaver feces in the water.[206] Increased glacial runoff due to warming temperatures has increased flooding events in rural Alaska.[207] For rural communities, which tend to be situated on coastal lands or riverbanks, this flooding is a real concern.[208] In a flood, the sudden inundation of water can overwhelm a primitive drinking-water or wastewater treatment facility, causing sewage and contaminated water to overflow into the community. The contaminated water can carry *Giardia*, *Cryptosporidium*, or other waterborne pathogens. If the contaminated water is utilized by the community, which it often would be when no other source of water exists, the risk of a waterborne outbreak is high. This is the risk that Alaska must contain and stem before further climatic changes result in increased incidences of flooding.

Waterborne diseases such as *Giardia* and *Cryptosporidium* pose a real threat to rural Alaskan communities. These diseases can easily contaminate a water source and rapidly spread through a rural community before a response can be mounted against them. Although International and U.S. laws focus on monitoring and surveillance of waterborne pathogens, and the

206. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 475 (2008).

207. Environmental Protection Agency, *Climate Change and Alaska*, EPA 236-F-98-007b, Sept. 1998, http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BMRWA/$File/ak_impct.pdf.

208. Jeremy J. Hess et al., *Climate Change: The Importance of Place*, 35 AM. J. PREV. MED. 468, 474 (2008).

treatment of water to prevent infection by these pathogens, rural Alaska remains vulnerable because of its more primitive drinking and wastewater treatment facilities, and its susceptibility to having its water sources contaminated by climatic events such as flooding.

A proactive approach by Alaska is required. Rural communities must obtain better water supply infrastructure to protect their water sources, both surface and groundwater, against potential climatic events and waterborne pathogen contamination. These communities must also receive more community public health education about what to do in instances of flooding, and they must receive ample assistance and resources before a climatic event takes place. Additionally, these communities, often mostly isolated from other communities and population centers, must be provided infrastructure that is able to bring clean water to the areas following a climatic event. Without clean water sources, these communities will face the possibility of destruction in this age of climate change.