Framing Climate Change Impacts on Water Resources and Health
Pathways for Weather to Affect Health: Example = Diarrheal Disease

Distal Causes
- Temperature
- Humidity
- Precipitation

Living conditions (water supply and sanitation)
- Food sources and hygiene practices

Proximal Causes
- Survival/replication of pathogens in the environment
- Contamination of water sources
- Contamination of food sources
- Rate of person to person contact

Infection Hazards
- Consumption of contaminated water
- Consumption of contaminated food
- Contact with infected persons

Health Outcome
- Incidence of mortality and morbidity attributable to diarrhea
- Vulnerability (e.g., age and nutrition)
<table>
<thead>
<tr>
<th>Climate change</th>
<th>Environmental effect</th>
<th>Recreational water-transmitted pathogen fate and behaviour</th>
<th>Recreational water-transmitted pathogens, examples</th>
<th>Recreational water types affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature increase</td>
<td>Water temperature increase</td>
<td>Growth of pathogens</td>
<td>Acanthamoeba, Aeromonas, Cyanobacteria, Naegleria fowleri, Pseudomonas aeruginosa, Trichobilharzia, Vibrio</td>
<td>Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inactivation/die-off of pathogens</td>
<td>Adenovirus, Cryptosporidium, E. coli O157, enterovirus, Giardia, hepatitis A virus, Leptospira, norovirus, rotavirus, Shigella, Staphylococcus aureus,</td>
<td>Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features</td>
</tr>
<tr>
<td></td>
<td>Elevated water temperature and water flow</td>
<td>Elevated concentrations of pathogens in surface water</td>
<td>Adenovirus, Cryptosporidium, E. coli O157, enterovirus, Giardia, hepatitis A virus, norovirus, rotavirus, Shigella</td>
<td>Surface water (fresh and marine)</td>
</tr>
<tr>
<td>Rainfall intensity and frequency</td>
<td>Run-off, sewage overflows and flooding</td>
<td>Intensity and frequency of peak concentrations of pathogens in surface water</td>
<td>Adenovirus, Cryptosporidium, E. coli O157, enterovirus, Giardia, hepatitis A virus, norovirus, rotavirus, Shigella</td>
<td>Surface water (fresh and marine)</td>
</tr>
<tr>
<td></td>
<td>Resuspension of river sediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in water volume</td>
<td>Pathogen concentrations</td>
<td>Acanthamoeba, Aeromonas, Adenovirus, Cryptosporidium, Cyanobacteria, E. coli O157, enterovirus, Giardia, hepatitis A virus, Leptospira, norovirus, rotavirus, Shigella, Staphylococcus aureus, Trichobilharzia, Vibrio</td>
<td>Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features</td>
</tr>
<tr>
<td></td>
<td>Changes in physiochemical composition of water e.g. salinity</td>
<td>Inactivation/die-off of pathogens</td>
<td>Acanthamoeba, Aeromonas, Adenovirus, Cryptosporidium, Cyanobacteria, E. coli O157, enterovirus, Giardia, hepatitis A virus, Leptospira, norovirus, rotavirus, Shigella, Staphylococcus aureus, Trichobilharzia</td>
<td></td>
</tr>
<tr>
<td>Water availability</td>
<td>Decrease in availability of recreational water sites</td>
<td>Growth of pathogens</td>
<td>Vibrio</td>
<td>Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features</td>
</tr>
</tbody>
</table>
As global warming continues to shrink water supplies in already water-stress regions of the world and populations become increasingly dependent on decreasing sanitary water sources for all their basic needs, the global burden of water-related diseases will increase.

- Globally, over 1 billion people lack access to safe drinking water
- 2.5 billion lack access to adequate sanitation
- Estimated that 5 million people globally, primarily kids, die from water-related diseases annually
2012 Flood in Pakistan (September)

- Monsoon floods in Pakistan during September, killed more than 400 people and affected more than 4.5 million others:
  - Tens of thousands have been made homeless by heavy flooding in the provinces of Balochistan and Sindh – where 2.8 million were affected.
  - Pakistan has suffered devastating floods in the past few years.
  - The worst floods were in 2010, when almost 1,800 people were killed and 21 million were affected.

Pakistan has suffered devastating floods in the past few years.
Health Impacts of Floods

- Immediate deaths and injuries
- Non-specific increases in mortality
- Infectious diseases – leptospirosis, hepatitis, diarrhoeal, respiratory, and vector-borne diseases
- Exposure to toxic substances
- Mental health effects
- Indirect effects
- Increased demands on health systems.
## Flooding: Direct Health Effects

<table>
<thead>
<tr>
<th>Causes</th>
<th>Health Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream flow velocity; topographic land features; absence of warning; rapid speed of flood onset; deep floodwaters; landslides; risk behaviour; fast flowing waters carrying boulders and fallen trees</td>
<td>Drowning Injuries</td>
</tr>
<tr>
<td>Contact with water</td>
<td>Respiratory diseases; shock; hypothermia; cardiac arrest</td>
</tr>
<tr>
<td>Contact with polluted water</td>
<td>Wound infections; dermatitis; conjunctivitis; gastrointestinal illness; ear, nose and throat infections; possible serious waterborne diseases</td>
</tr>
<tr>
<td>Increase of physical and emotional stress</td>
<td>Increase of susceptibility to psychosocial disturbances and cardiovascular incidents</td>
</tr>
</tbody>
</table>
# Flooding: Indirect Health Effects

<table>
<thead>
<tr>
<th>Causes</th>
<th>Health Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage to water supply systems; sewage and sewage disposal damage; insufficient supply of drinking water; insufficient water supply for washing</td>
<td>Possible waterborne infections (enterogenic <em>E. coli</em>, shigella, hepatitis A, Leptospirosis, giardiasis, camplylobacter) dermatitis, and conjunctivitis</td>
</tr>
<tr>
<td>Disruption of transport systems</td>
<td>Food shortage; disruption of emergency response</td>
</tr>
<tr>
<td>Underground pipe disruption; dislodgement of storage tanks; overflow of toxic waste sites; release of chemicals; rupture of gasoline storage tanks may lead to fires</td>
<td>Potential acute or chronic effects of chemical pollution</td>
</tr>
<tr>
<td>Standing waters; heavy rainfalls; expanded range of vector habitats</td>
<td>Vector-borne diseases</td>
</tr>
<tr>
<td>Rodent and other pest migration</td>
<td>Possible diseases caused by rodents or other pests</td>
</tr>
<tr>
<td>Disruption of social networks; loss of property, jobs and family members and friends</td>
<td>Possible psychosocial disturbances</td>
</tr>
<tr>
<td>Clean-up activities following floods</td>
<td>Electrocutions; injuries; lacerations; skin punctures</td>
</tr>
<tr>
<td>Destruction of primary food products</td>
<td>Food shortage</td>
</tr>
<tr>
<td>Damage to health services; disruption of “normal” health service activities</td>
<td>Decrease of “normal” health care services, insufficient access to medical care</td>
</tr>
</tbody>
</table>
Rainfall: transport and dissemination of infectious agents

Flooding: sewage treatment plants overflow; water sources contaminated, secondary shortage of clean drinking water

Sea level rise: enhances risk of severe flooding

Higher temperatures: Increases growth and prolongs survival rates of infectious agents

Drought: increases concentrations of pathogens, impedes hygiene

- Most documented waterborne disease outbreaks occur after extreme precipitation events.
- 9 million cases of waterborne disease occur annually in the U.S.
- Foodborne diseases cause 76 million illnesses a year, with 325,000 hospitalized and 5,000 deaths
Climate Change & Diarrhea

- Leading cause of child mortality across the world with ~ 1.6 million annual deaths in children under 5 years of age.

- Worldwide, 1.1 billion individuals lack access to improved, safe drinking water sources and 2.5 billion lack improved sanitation.

- Children, elderly and those with chronic diseases and weakened immune systems at greatest risk.

- Studies in India, Peru and China found a 1°Celsius rise in ambient temperature increased diarrheal disease anywhere from 5.6%-16% and found hospital admissions from diarrhea in children increased 8% in Lima, Peru during El Nino period.
Climate Change & Diarrhea

- In the U.S by 2100, the Great Lakes climate modeling projects a 50% to 120% increase in overflow events.

- An analysis of 87 waterborne disease outbreaks from 1910-2012 showed that heavy rainfall and flooding is associated with Vibrio and Leptospira infections most often.
Diarrhoea increases by 8% for each 1°C increase in temperature

- Waterborne disease outbreaks in the U.S. exhibit a positive correlation with excess precipitation events.
### Waterborne Infectious Diseases

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Parasites</th>
<th>Viruses</th>
<th>Fungus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrio species</td>
<td>Cryptosporidium</td>
<td>Hep A</td>
<td>Cryptococcus</td>
</tr>
<tr>
<td>E. Coli</td>
<td>Giardia</td>
<td>Polio</td>
<td>Aspergillus</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>Toxoplasmosis</td>
<td>Norovirus</td>
<td>Harmful Algae Bloom (HAB)</td>
</tr>
<tr>
<td>Salmonella</td>
<td>Cyclospora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptospira</td>
<td>Naegleria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legionella</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• **Toxigenic E. Coli (O157:H7)** from contaminated food and water.

• Bloody diarrhea, vomiting—may lead to kidney failure and even death

• **Campylobacter**—common cause of food poisoning from meats/unpasteurized dairy products/contaminated water.
Association between precipitation and waterborne disease outbreaks/Toxigenic E. Coli

Amy Greer, PhD et al. CMAJ 2008;178:715-722
Bacterial Contamination

- **Salmonella** - common cause of food poisoning

Temperature and Enteric Disease

RR of **Salmonella** increased by 1.2% per degree above - 10°C

RR of **Campylobacter** increased by 2.2% (4.5% in Newfoundland) per degree above - 10°C

RR of **E. coli** increased by 6.0% per degree above - 10°C

Fleury et al. 2006
• **Leptospira**-spread through the urine of infected animals, rodents, through the soil and water, and during flooding. Infections in urban kids increasing.

• Higher temperatures are associated with higher rates of production and disease.
**Bacteria: Vibrio Species & Legionella**

- **Vibrio** is strongly influenced by climate—both fresh and marine waters.

- **V. Cholera** causes estimated 3-5 million cases and 100,000-120,000 deaths yearly world-wide. Young children in endemic areas most affected.

- Climate warming can increase pathogen development and survival rates, disease transmission and host vulnerability.
Legionella (Legionnaire’s Disease)-respiratory illness transmitted solely by water. Warm water and perhaps other factors, like association with amoebas, influence the potential to colonize water systems.
Cryptosporidium - 2,000-3,000 cases annually in the U.S. through livestock waste & contaminated water.

Cryptosporidium oocysts detected in 65% to 97% of surface waters tested in the U.S.

Common disinfectants, like chlorination is ineffective.

1993 outbreak in Milwaukee was the largest outbreak ever documented in the U.S. with 400,000 cases and 100 deaths.

In 1997, 2,566 cases were reported from 45 states.
Parasitic Disease

- **Giardia lamblia** - second most common parasite in the U.S.
- Cyst found in raw surface water from animal and human feces
Viruses are heat resistant and likely to survive sewer treatment processes. Viruses found in shellfish contaminated with wastewater and fecal sources.

- Hepatitis A
- Norovirus
- Norwalk virus

Fungal Diseases

- Cryptococcus
- Aspergillus

Harmful Algae Blooms (HAB)
Prevention: Waterborne Disease

- Improve quality and quantity of drinking at source, at the tap, or in the storage vessel.
- Interrupt routes of transmission by emptying accumulated water sources
- Chlorinate water
- Change hygiene behavior, like hand washing
- Breastfeeding first 6 months of life
- Proper use of latrines
Prevention: Waterborne Disease

- Careful disposal of all waste products
- Proper maintenance of water supply, sanitation systems, pumps and wells
- Good food hygiene - wash before eating, protect from flies
- Improved immunizations practices, especially rotavirus
- Develop or enhance public health surveillance system
- Faster responses to emergent and dangerous pandemic strains of pathogenic infections.
- Health education programs across the country
Climate impacts on Water and public health and tracking climate readiness for a country

This exercise offers insight into enhancing climate readiness in water safety and health.

The exercise is divided into four parts:

1. An overview of the effects of extreme weather and climate change on the public health infrastructure;

2. Opportunities for integrating climate readiness into existing programs;

3. Tracking climate readiness; and,

4. A review of the evidence that a climate readiness approach can offer co-benefits to health, financial wellbeing, and the environment.
Activity 1: Climate Impacts

Being familiar with any country climate assessment and/or action plan:

I. What are the immediate and long-term effects of extreme weather and climate change on water safety in your country?

- **Step 1.** Identify the top 1-3 climate risks to your country.

- **Step 2.** Identify how these climate risks will impact water safety and health.

- **Step 3.** List the agency or department that addresses each water safety impact and health.

- **Step 4.** List the existing programs designed to reduce the impacts identified under Step 2.

- **Step 5.** Based on your responses to Steps 1-4, place an asterisk next to the climate risk that would be most appropriate to prioritize for the remainder of this assessment.
Activity II: Negative health outcomes

II. What are the potential negative health outcomes associated with the impacts of climate change on water safety?

- **Step 1.** List the climate risk identified with an asterisk in Activity I.a.
- **Step 2.** In the left-hand column of the Table A-2, list three impacts associated with this climate risk (as identified in Activity I.a.).
- **Step 3.** List the potential negative health outcomes associated with these impacts.
- **Step 4.** List the populations that are particularly vulnerable to these impacts.
- **Step 5.** List the existing public health tracking / surveillance programs, policies, and interventions designed to reduce the negative health outcomes identified under Step 3.
- **Step 6.** List the co-benefits of the public health programs to the water safety programs outlined in Activity I.a.
<table>
<thead>
<tr>
<th></th>
<th>Impacts on water safety</th>
<th>Department/Agency</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate Risk 1:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Climate Risk 2:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Climate Risk 2:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table A-2

<table>
<thead>
<tr>
<th>Climate Risk</th>
<th>Health effects</th>
<th>vulnerable populations</th>
<th>programs</th>
<th>co-benefits to water safety program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>