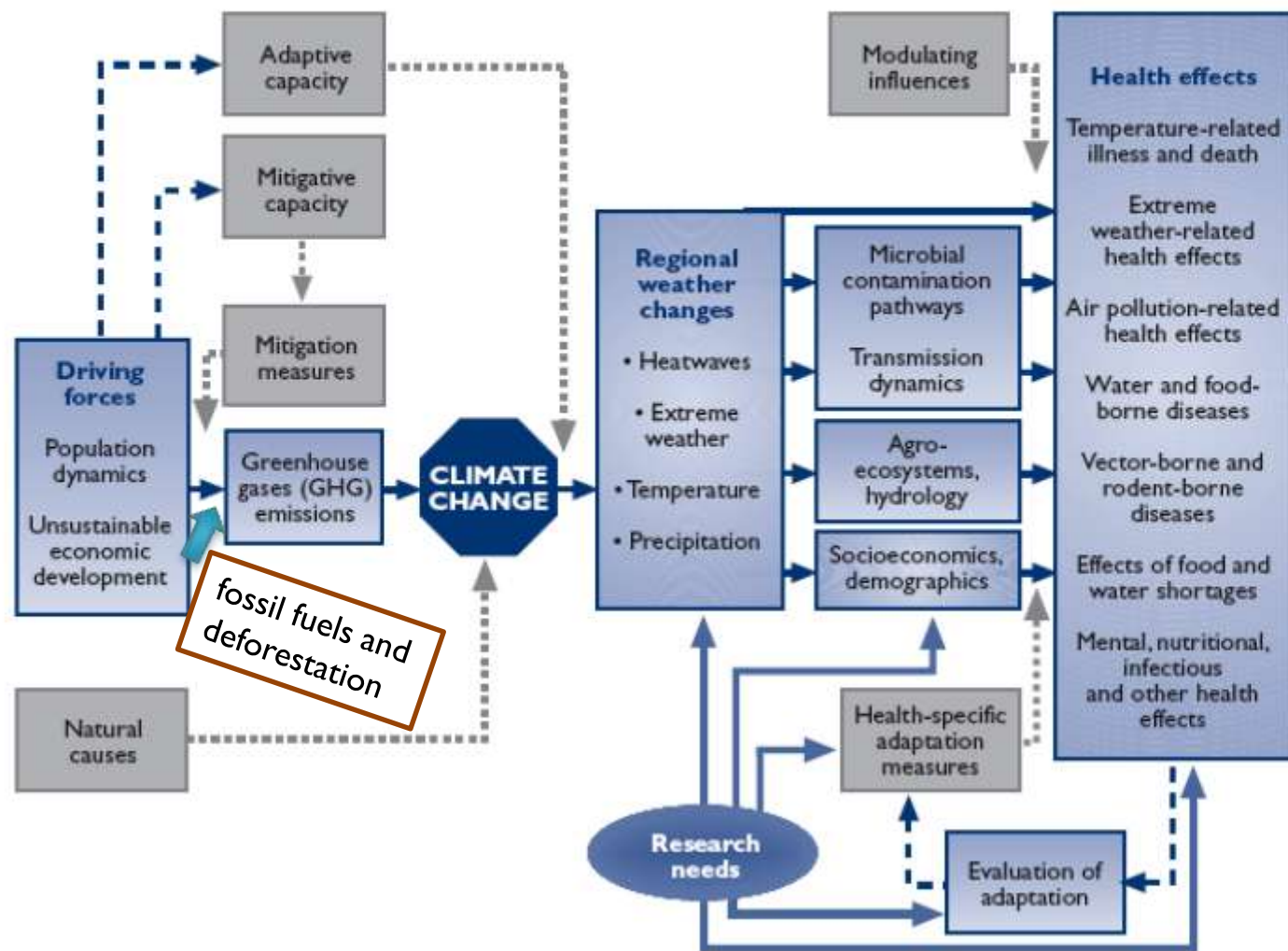


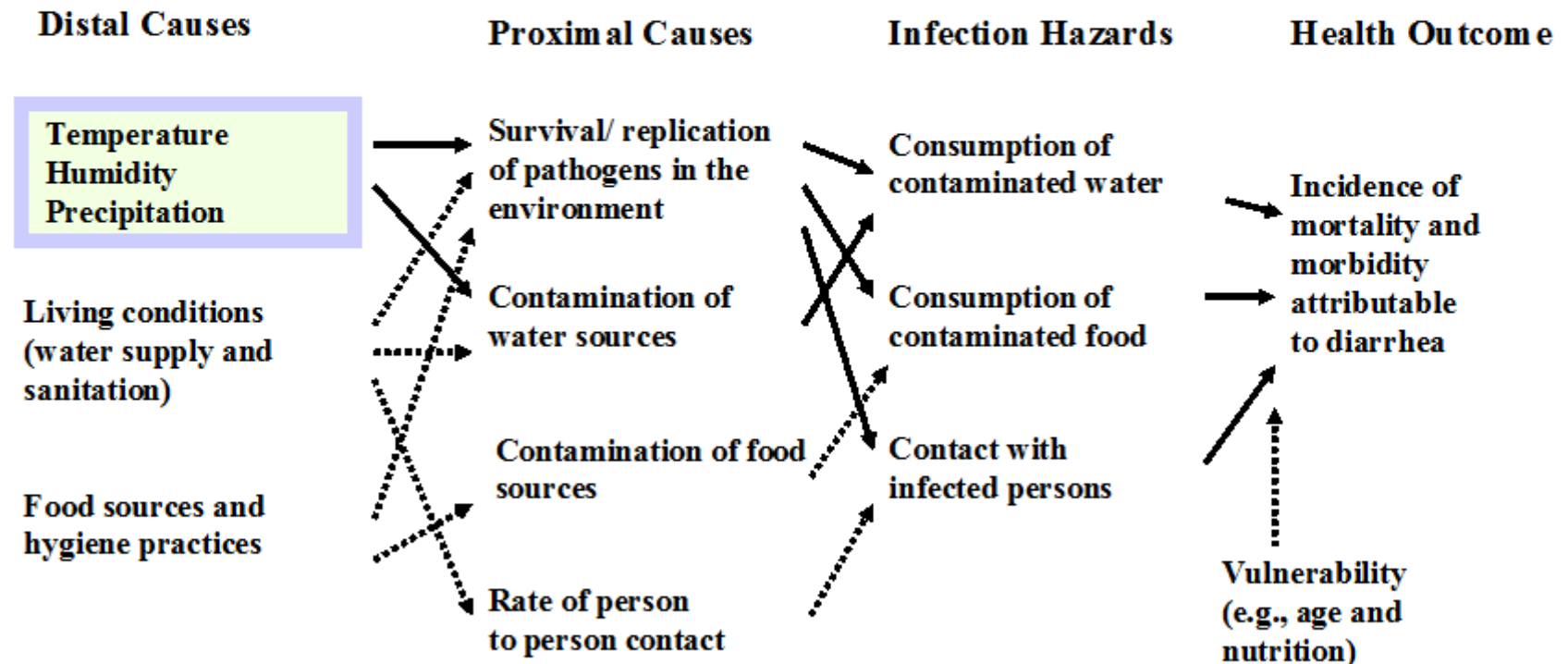


**Framing Climate Change Impacts on
Water Resources and Health**

Health Impacts of Climate Change



Pathways for Weather to Affect Health: Example = Diarrheal Disease

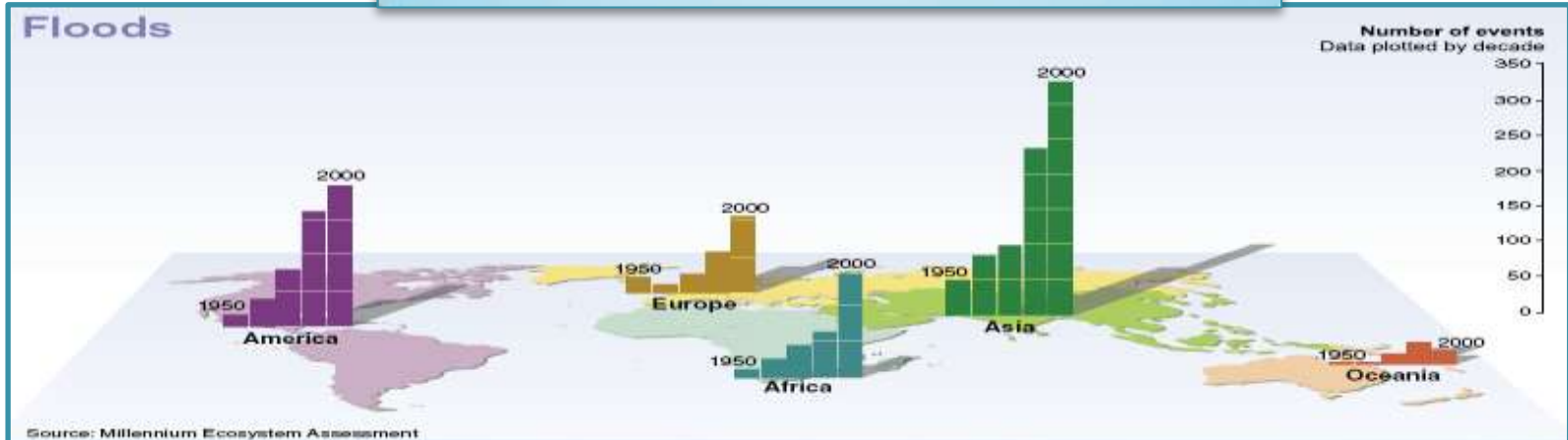


Climate change	Environmental effect	Recreational water-transmitted pathogen fate and behaviour	Recreational water-transmitted pathogens, examples	Recreational water types affected
Temperature increase	Water temperature increase	Growth of pathogens	<i>Acanthamoeba</i> , <i>Aeromonas</i> , <i>Cyanobacteria</i> , <i>Naegleria fowleri</i> , <i>Pseudomonas aeruginosa</i> , <i>Trichobilharzia</i> , <i>Vibrio</i>	Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features
		Inactivation/die-off of pathogens	Adenovirus, <i>Cryptosporidium</i> , <i>E. coli</i> O157, enterovirus, <i>Giardia</i> , hepatitis A virus, <i>Leptospira</i> , norovirus, rotavirus, <i>Shigella</i> , <i>Staphylococcus aureus</i> ,	Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features
	Elevated water temperature and water flow	Elevated concentrations of pathogens in surface water	Adenovirus, <i>Cryptosporidium</i> , <i>E. coli</i> O157, enterovirus, <i>Giardia</i> , hepatitis A virus, norovirus, rotavirus, <i>Shigella</i>	Surface water (fresh and marine)
Rainfall intensity and frequency	Run-off, sewage overflows and flooding	Intensity and frequency of peak concentrations of pathogens in surface water	Adenovirus, <i>Cryptosporidium</i> , <i>E. coli</i> O157, enterovirus, <i>Giardia</i> , hepatitis A virus, norovirus, rotavirus, <i>Shigella</i>	Surface water (fresh and marine)
	Resuspension of river sediments			
Water availability	Decrease in water volume	Pathogen concentrations	<i>Acanthamoeba</i> , <i>Aeromonas</i> , Adenovirus, <i>Cryptosporidium</i> , <i>Cyanobacteria</i> , <i>E. coli</i> O157, enterovirus, <i>Giardia</i> , hepatitis A virus, <i>Leptospira</i> , norovirus, rotavirus, <i>Shigella</i> , <i>Staphylococcus aureus</i> , <i>Trichobilharzia</i> , <i>Vibrio</i>	Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features
	Changes in physiochemical composition of water e.g. salinity	Inactivation/die-off of pathogens	<i>Acanthamoeba</i> , <i>Aeromonas</i> , Adenovirus, <i>Cryptosporidium</i> , <i>Cyanobacteria</i> , <i>E. coli</i> O157, enterovirus, <i>Giardia</i> , hepatitis A virus, <i>Leptospira</i> , norovirus, rotavirus, <i>Shigella</i> , <i>Staphylococcus aureus</i> , <i>Trichobilharzia</i>	
		Growth of pathogens	<i>Vibrio</i>	
	Decrease in availability of recreational water sites			

Decrease in availability of

Surface water (fresh and marine), natural or green pools, paddling pools, interactive water features

Flooding & Storm Surge



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.



BBC news: 28 Sept 2012

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

Causes	Health Implications
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	Drowning Injuries
Contact with water	Respiratory diseases; shock; hypothermia; cardiac arrest
Contact with polluted water	Wound infections; dermatitis; conjunctivitis; gastrointestinal illness; ear, nose and throat infections; possible serious waterborne diseases
Increase of physical and emotional stress	Increase of susceptibility to psychosocial disturbances and cardiovascular incidents

Flooding: Indirect Health Effects

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



Waterborne Infectious Diseases



- ① **Rainfall:** transport and dissemination of infectious agents
- ① **Flooding:** sewage treatment plants overflow; water sources contaminated, secondary shortage of clean drinking water
- ① **Sea level rise:** enhances risk of severe flooding
- ① **Higher temperatures:** Increases growth and prolongs survival rates of infectious agents
- ① **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

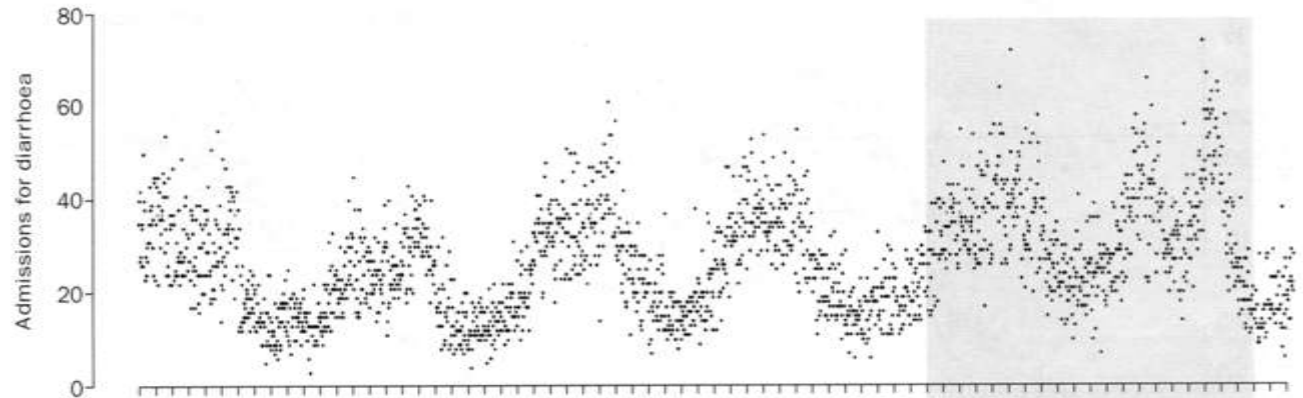
- Leading cause of child mortality across the world with ~ 1.6 million annual deaths in children under 5 years of age.
- Worldwide, 1.1 billion individuals lack access to improved, safe drinking water sources and 2.5 billion lack improved sanitation.
- Children, elderly and those with chronic diseases 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

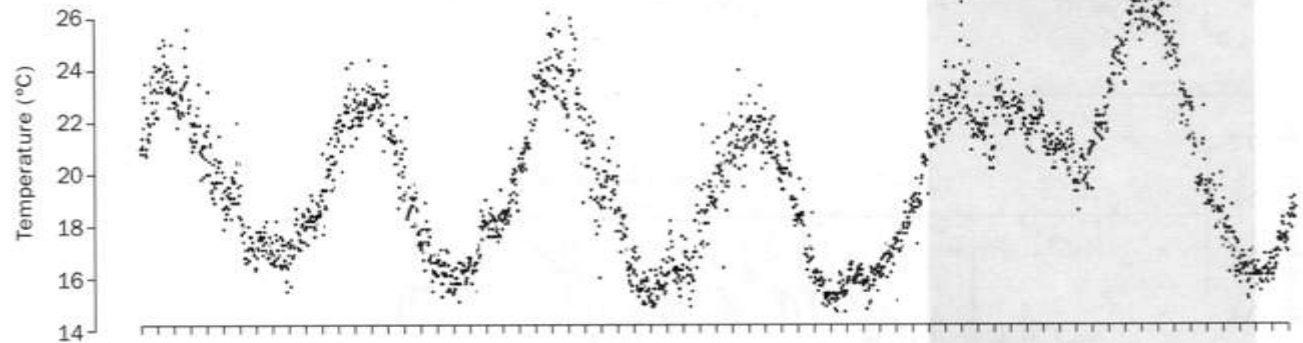
- In the U.S by 2100, the Great Lakes climate modeling projects a 50% to 120% increase in overflow events
- An analysis of 87 waterborne disease outbreaks from 1910-2012 showed that heavy rainfall and flooding is associated with *Vibrio* and *Leptospira* infections most often.

Climate Change & Diarrhea

**Daily
diarrhoea
admissions**



**Daily
temperature**



Diarrhoea increases by 8% for each 1°C increase in temperature

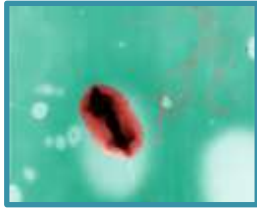
- Waterborne disease outbreaks in the U.S. exhibit a positive correlation with excess precipitation events



Waterborne Infectious Diseases



Bacteria	Parasites	Viruses	Fungus
<ul style="list-style-type: none">➤ Vibrio species➤ E. Coli➤ Campylobacter➤ Salmonella➤ Leptospira➤ Legionella	<ul style="list-style-type: none">➤ Cryptosporidium➤ Giardia➤ Toxoplasmosis➤ Cyclospora➤ Naegleria	<ul style="list-style-type: none">➤ Hep A➤ Polio➤ Norovirus	<ul style="list-style-type: none">➤ Cryptococcus➤ Aspergillus ➤ Harmful Algae Bloom (HAB)

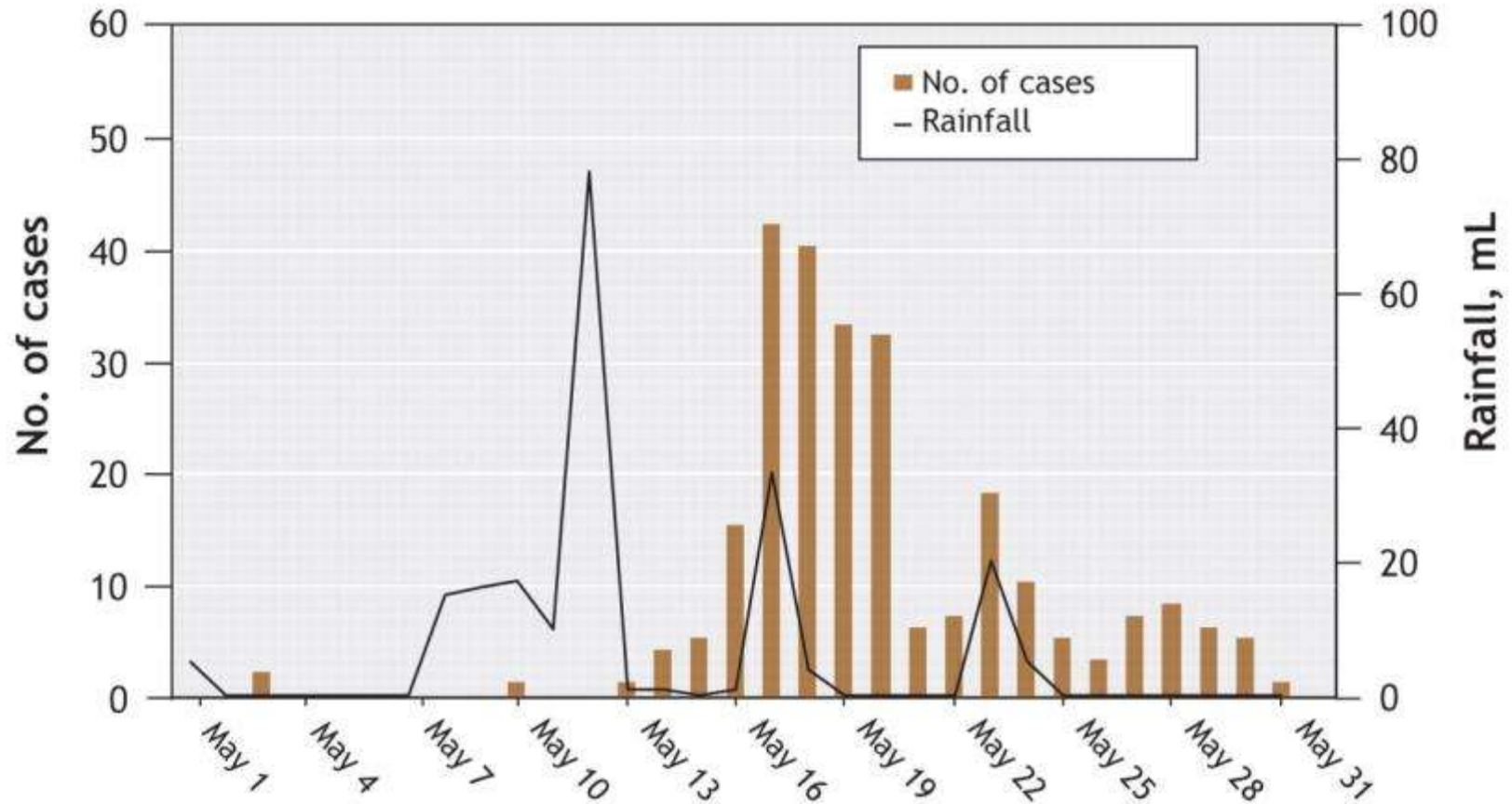


Bacterial Contamination



- **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



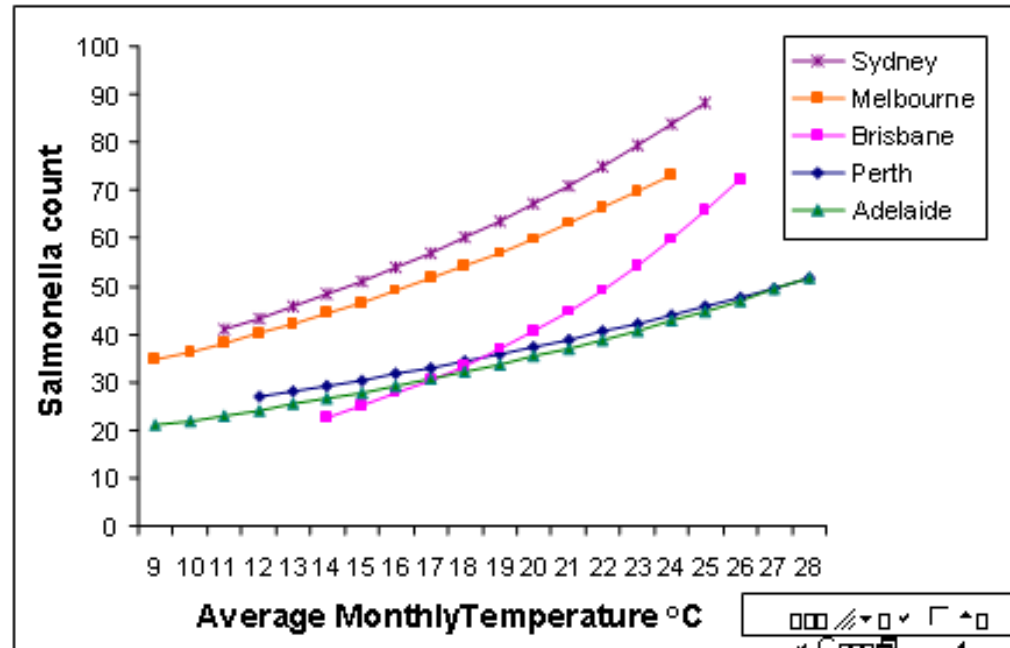


Bacterial Contamination



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

Model-fitted relationship of monthly *Salmonellosis* case counts in relation to monthly av. temperature in five Australian cities, 1991-2001

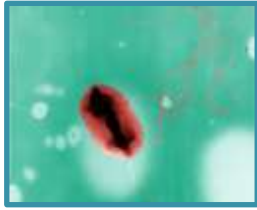


Temperature and Enteric Disease

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

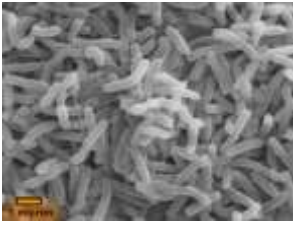
RR of **E. coli** increased by 6.0% per degree above - 10°C



Bacterial Contamination

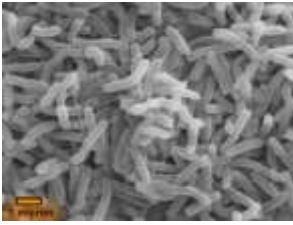


- **Leptospira**-spread through the urine of infected animals, rodents, through the soil and water, and during flooding Infections in urban kids increasing.
- Higher temperatures are associated with higher rates of production and disease.



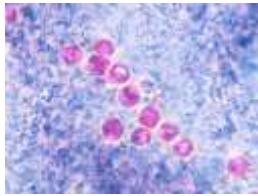
Bacteria: **Vibrio** Species & Legionella

- **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.

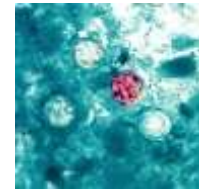


Bacteria: Vibrio Species & Legionella

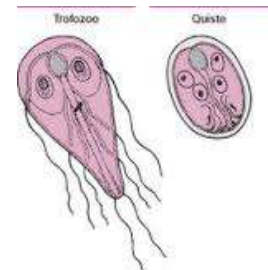
- **Legionella** (Legionnaire's Disease)-respiratory illness transmitted solely by water. Warm water and perhaps other factors, like association with amoebas, influence the potential to colonize water systems.

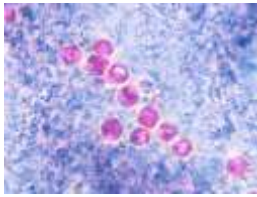


Parasitic Disease

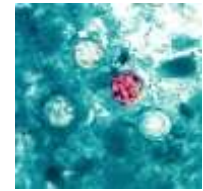


- **Cryptosporidium**-2,000-3,000 cases annually in the U.S.- through livestock waste & contaminated water
- Cryptosporidium oocytes detected in 65% to 97% of surface waters tested in the U.S.
- Common disinfectants, like chlorination is ineffective
- 1993 outbreak in Milwaukee was the largest outbreak ever documented in the U.S. with 400,000 cases and 100 deaths.
- In 1997, 2,566 cases were reported from 45 states

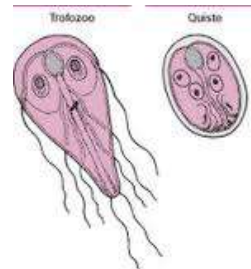




Parasitic Disease



- **Giardia lamblia**-second most common parasite in the U.S.
- Cyst found in raw surface water from animal and human feces

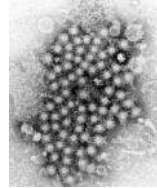


Viral, Fungal & HAB Diseases

- **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

Exercise

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 A-1

	Impacts on water safety	Department/Agency	Programs
Climate Risk 1:			
Climate Risk 2:			
Climate Risk 2:			

Table A-2

Climate Risk				
	Health effects	vulnerable populations	programs	co-benefits to water safety program
Impact 1				
Impact 2				
Impact 3				