FACS
Forensic Analytical Consulting Services

A Historical Perspective on Waterborne Illness: Implications for the Future of OEHS

Megan Canright Racicot, MPH, CIH
Director of Scientific Operations

Yuma Pacific Southwest 50th Annual Meeting
January 23, 2025

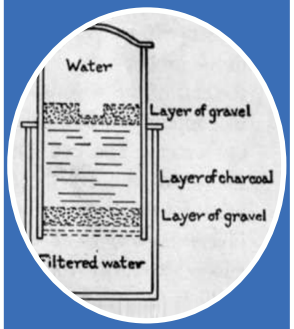
Agenda

- A Brief History of Water & Human Health
- Financial Implications of Waterborne Illness
- Review of Select Waterborne Contaminants
- Implications for the Future of OEHS

A Brief History of Water & Human Health

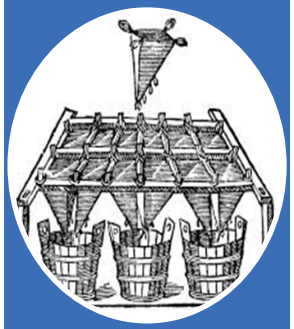
Ancient Water Treatment

Before 2000 BC, heating, sun was used to treat water



2000 BC crude gravel & sand filtration used in India/ Greece

1500 BC Ancient Egyptians utilize coagulation



500 BC Hippocrates proposed cloth bag filtration

300-200 BC Ancient Romans implement aqueducts

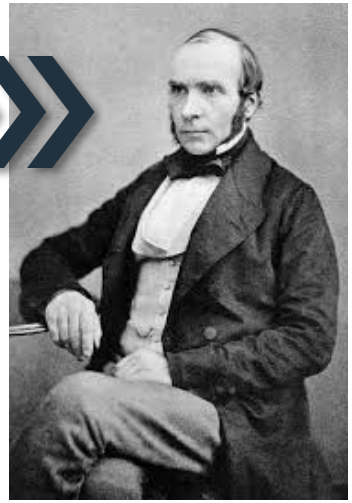
200 BC Archimedes invents the screw pump

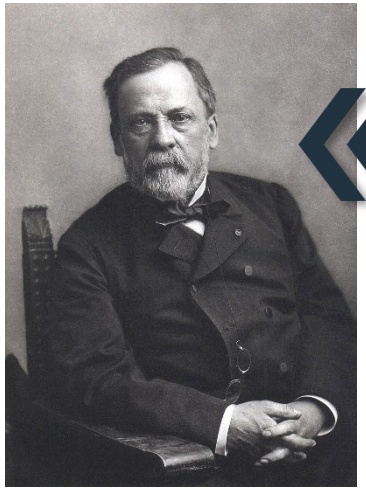
Source: Association of Water Technologies

Brief History of Waterborne Illness

Prior to the 1850's, "Miasma" theory prevailed as medical explanation for infectious disease

In 1850's Dr. John Snow began to pose alternative theories related to the communication of cholera





In 1861 Dr. Louis Pasteur demonstrates the germ theory, revolutionized public health

Source: Centers for Disease Control & Prevention

Brief History of Waterborne Illness

1854

Broad Street Pump cholera outbreak; removal of pump handle

Development of sanitary sewer management

1897

"bleaching powder" temporarily added to municipal water supply in Maidstone, England to try to treat a typhoid epidemic

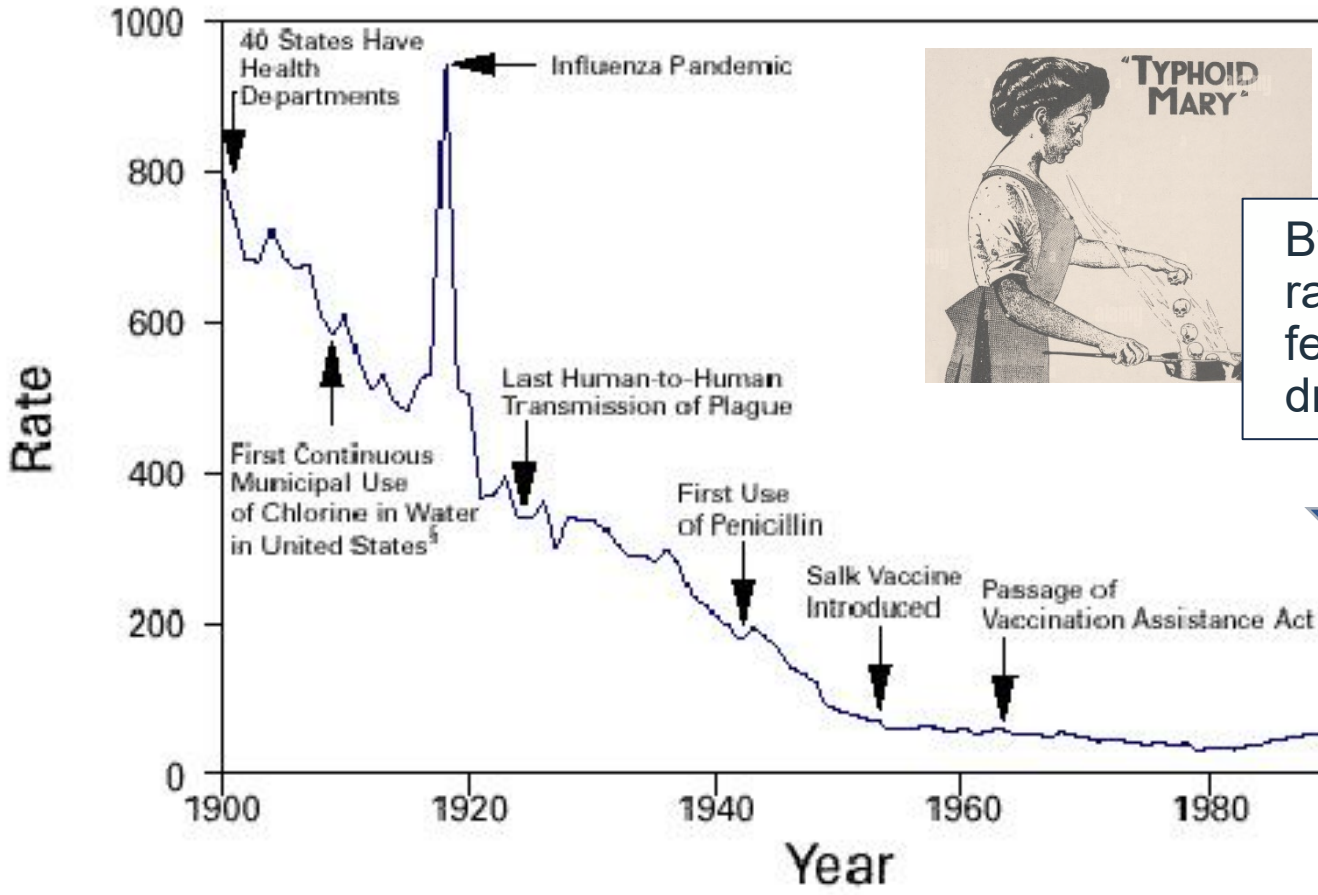
1908

Continuous chlorine first added to municipal water supply for disinfection

0.2-0.3 ppm

Source: Centers for Disease Control & Prevention

Implications of Drinking Water Treatment



By 1920, incidence rate for typhoid fever infection has dropped 64%

Source: Centers for Disease Control & Prevention

Modern Water Treatment

Source: Denver Water

In 1917, monochloramine is first added to drinking water in the Denver, CO

Lead helps to guard your health

YOU wouldn't live today in a house without an adequate plumbing system. For without modern plumbing, sickness might endanger your life.

Lead concealed in the walls and under the floors of many modern buildings helps to give the rest mentioned.

Lead pipe centuries old

Lead, therefore, is contributing to the health, comfort, and convenience of people today as it did when Rome was a center of civilization. Lead water and drainage pipes more than 1900 years old have been found in exactly the condition they were in when laid.

In some cities today the law specifies that lead pipe alone may be used to bring water from street mains into the building.

In drainage systems are lead traps made of lead pipe bent into the shape of the letter S, so that a little water will stay in the bend and prevent gases which collect in the pipe from getting out through the house.

The malleability of lead also makes it easy to change the direction of any pipe through the use of lead bends.

Joining the pipes

A plumber easily "wipes" a joint or repairs a pipe leak with lead and his solder. Because this alloy melts at the low temperature of 338 degrees it can be applied without melting the lead pipe, which melts at 620 degrees.

Lead is also poured into the flanges of pipe-joints to make them absolutely tight. Pipe threads are painted with white-lead or red-lead to make a tight connection. Where vibration or movement of pipes may loosen a poured joint, lead wool is used; lead shredded into threads is packed into the joint to a depth, sometimes more.

Rubber gaskets and half washers containing lead prevent leaking at joints and flanges.

Lead is used to beautify the modern bathroom. Red-lead and litharge, both lead oxides, are important ingredients in making the glossy white enamel covering the iron bodies of tub and basin and the glazed tile walls.

Lead in paint

While lead is invaluable in assuring comfort and proper sanitation, its best-known and most widespread use is as white-lead in paint. Such materials as wood would soon deteriorate unless protected with paint. And the paints that give the most thorough protection against the weather are based on white-lead.

The loss of invested capital through failure to protect the surfaces of property adequately has led property owners to paint frequently and well. As days and months go by, more and more of them are learning the wisdom of the phrase, "Save the surface and you save all." And they are using white-lead paint to prolong the lives of their houses.

Look for the Dutch Boy

National Lead Company makes white-lead and sells it mixed with pure linseed oil, under the name and trade-mark of Dutch Boy White-Lead. The figure of the Dutch Boy is reproduced on every keg and is a guarantee of exceptional purity.

Dutch Boy products also include red-lead, Dutch Boy Linseed Oil, Eureka Flat Paint, babbit metals and solder.

More about lead

If you use lead, or think you might use it in any form, write us or for specific information.

NATIONAL LEAD COMPANY

Source: National Institute of Health

By 1941, chlorine gas replaces calcium hypochlorite as major US disinfectant

294

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus. Dry Chemical Feed Devices, Etc. Newark, New Jersey

"THE ONLY SAFE WATER IS A STERILIZED WATER"

CHLORINATION

AMMONIATION

APPLICATION OF DRY CHEMICALS

EQUIPOISE CHLORINATOR

ROTOR CHLORINATOR

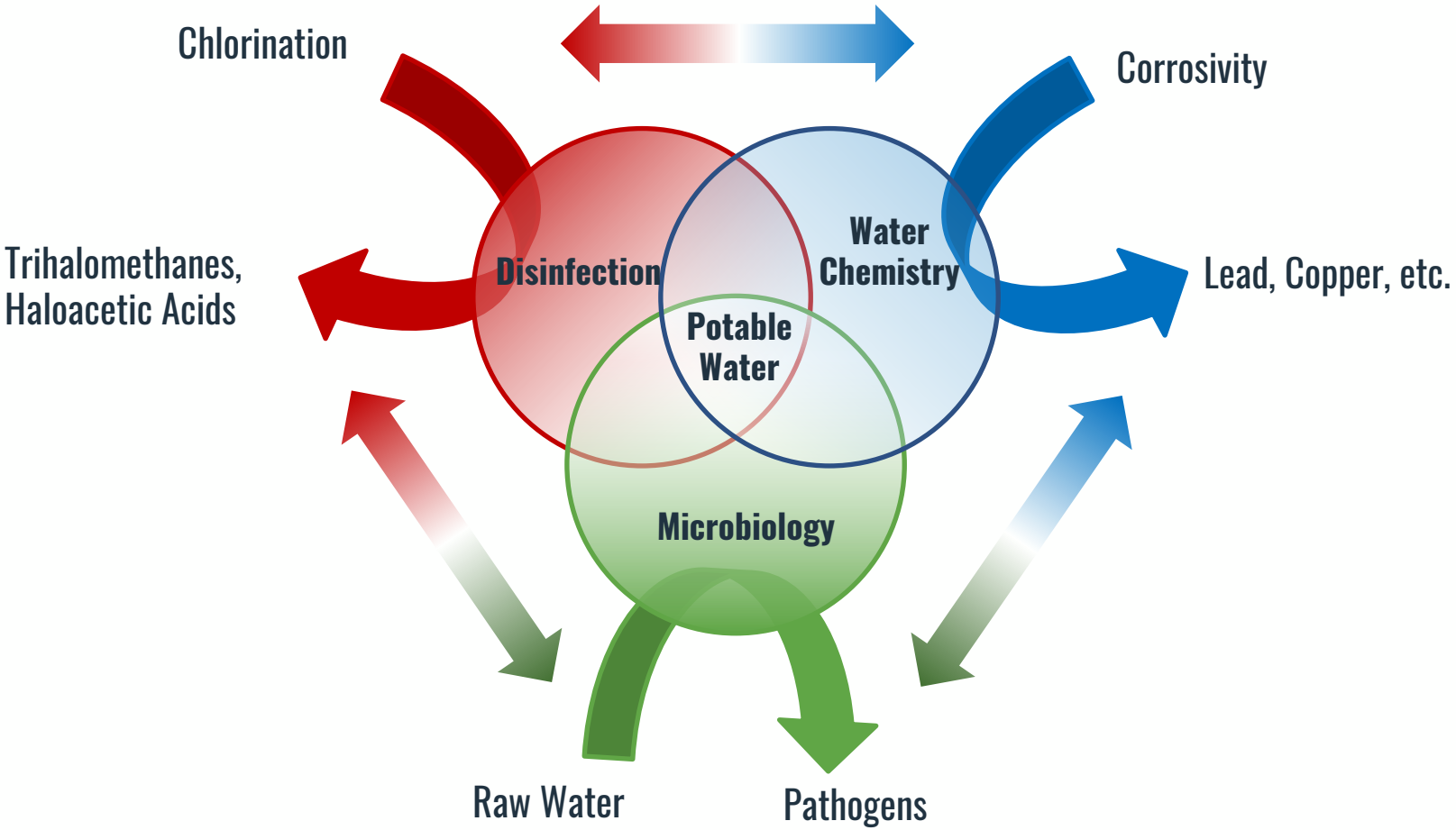
1940-41 Municipal Index

Source: Wallace & Tiernan Co.

1900-1950 majority US cities install lead water pipes

Lead hazards recognized since the 1800s

Implications of Drinking Water Treatment



Modern Waterborne Illness

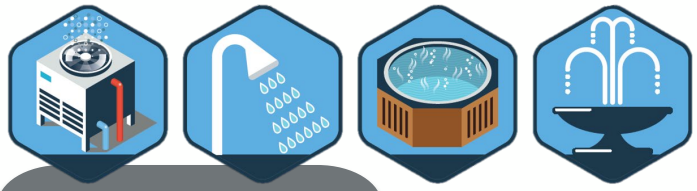
- **1976 American Legion Convention**
- **Bellevue-Stratford Hotel, Philly**
- **221 confirmed cases, 34 deaths**
- **Cause initially unknown**
  - Chemical warfare?
  - Swine flu, parakeet flu?
  - Radiation?
  - Cadmium poisoning?
- **Eventually identified as *Legionella***
  - "new" bacterium
  - Dr. Joseph McDade, Dr. George Gorman, Dr. James Feeley of CDC
- **Cause: cooling tower AND a temperature inversion… AND…?**

Source: Centers for Disease Control & Prevention

Modern Waterborne Illness

Brief History of Waterborne Illness

Source: Centers for Disease Control & Prevention



2015

- New York City Legionnaires' disease outbreaks
- Emergency regulations implemented in NY and NYC

2016

- At least 13 states implement mandatory lead testing in schools
- CA, NJ, CO, CT, RI, IA, DE, LA, MD, MA, WA, VT

Water Quality Regulations in the US

- Helps to curb pollution of US waterways from water vessels

1886, 1899
River and Harbor Acts

1912
US Public Health Service Act

- Prevention of waterborne illness is a key objective

- Provided federal assistance to states to construct sewage treatment plants

1948
Water Pollution Control Act

Water Quality Regulations in the US

- Allowed EPA to regulate pollution in national waters

1972
Clean Water Act

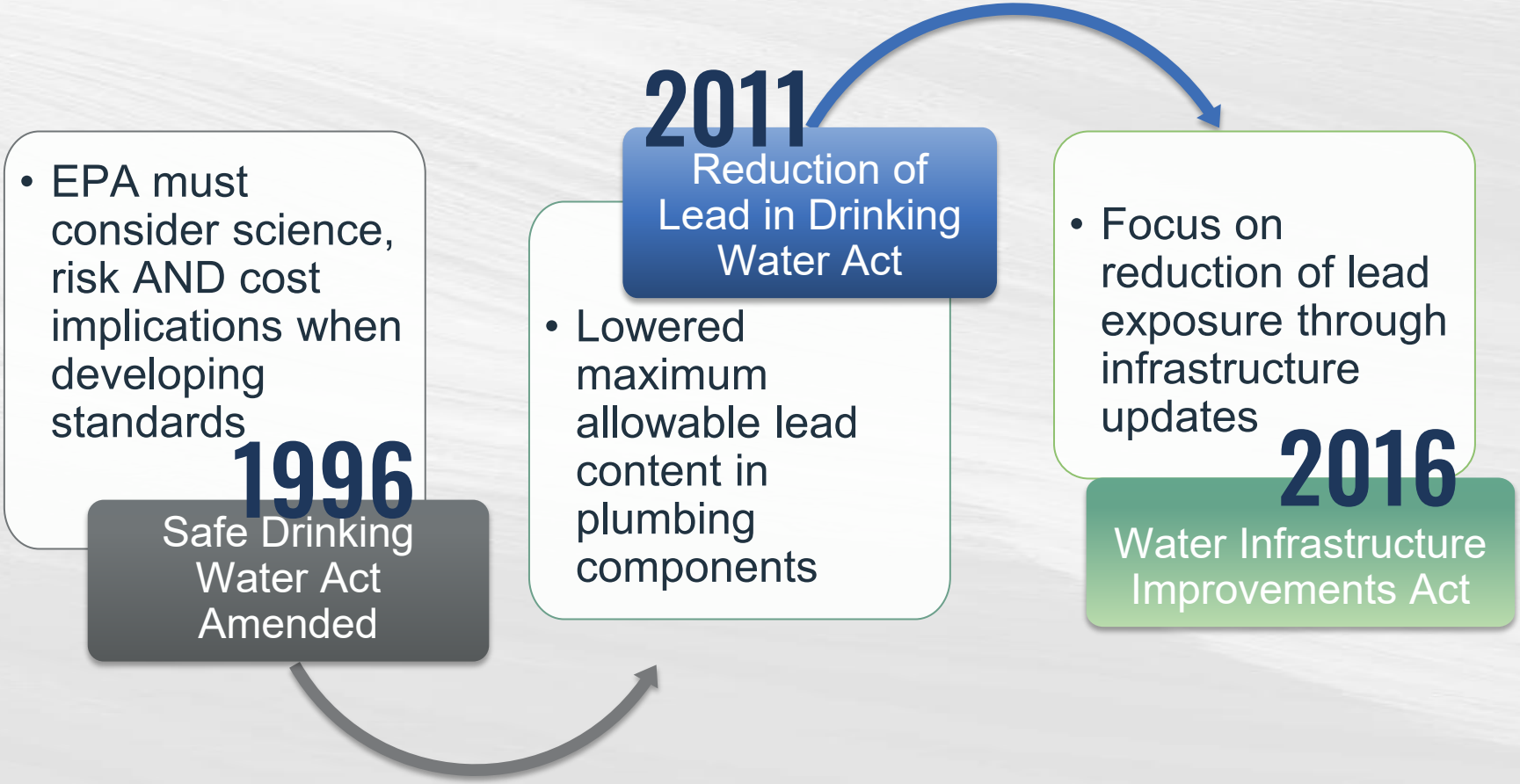
1974
Safe Drinking Water Act

- Allowed EPA to set and enforce drinking water standards

- Lead pipes, solder, flux banned in the US, 83 contaminants become regulated

1986
Safe Drinking Water Act Amended

Water Quality Regulations in the US



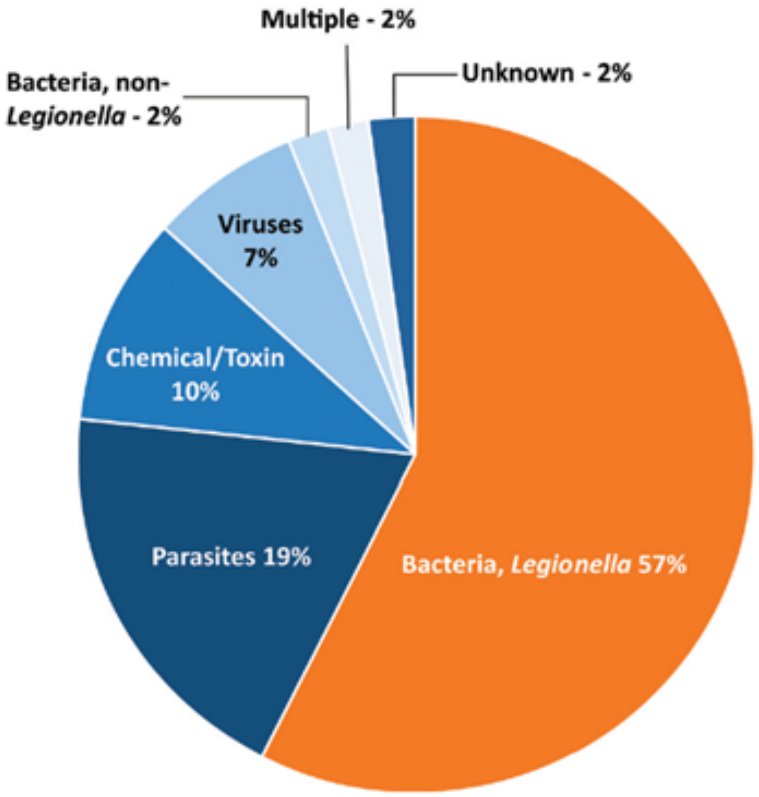
Water Quality Regulations in the US

EPA MCL	EPA AL[1]	EPA MCLG[2]	OEHHA PHG[3]	CA Prop 65 Warning Level[4]	American Academy Pediatrics[5]
"Not feasible"	10 ppb	0 ppb	0.2 ppb	0.2 ppb	1 ppb

- [1]Not health-based; level determined to be feasible for public water system to attain by adjusting water chemistry
- [2]Based on occurrence of "low level effects" and status as a Class B2 carcinogen
- [3]Based on neurobehavioral effects of exposure in children and hypertensive effects of exposure in adults; LOAEL of 10 ug/dL blood lead for both children and adults; assuming child water consumption of 1 L/day
- [4]Calculated based on the Prop 65 regulatory limit of 0.5 μg/day from any one source due to potential for reproductive and developmental effects; assuming child water consumption of 1 L/day
- [5]Action threshold; "there is no safe level of lead"

Financial Implications of Waterborne Illness

Multiple-Person Potable Water Outbreaks



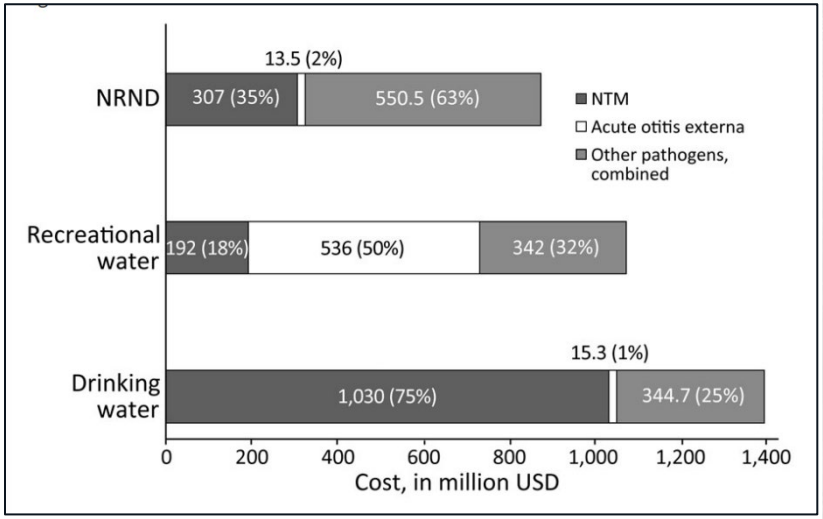
Source: Benedict et al. (2017)

FIGURE 3-4 NORS reported drinking water-associated disease outbreaks, 2013–2014 (n = 42).

Financial Implications of Waterborne Illness

In 2014…

- **>7 million infections (all)**
  - >1 million infections (drinking water)
- **~600,000 ER visits (all)**
- **~118,000 hospitalizations (all)**
- **~6,600 deaths (all)**
- **Estimated $3.3 billion in costs (all)**
- **Legionellosis**
  - ~6,000 hospitalizations (drinking water)
- **Non-tuberculous Mycobacteria**
  - ~35,600 hospitalizations (drinking water)
- **Pseudomonas (pneumonia & sepsis)**
  - ~1,800 hospitalizations (drinking water)



Source: Gerdes et. al. (2023)

Most hospitalizations and deaths caused by biofilm-associated pathogens
$2.39 billion annually

Financial Implications of Lead in Water

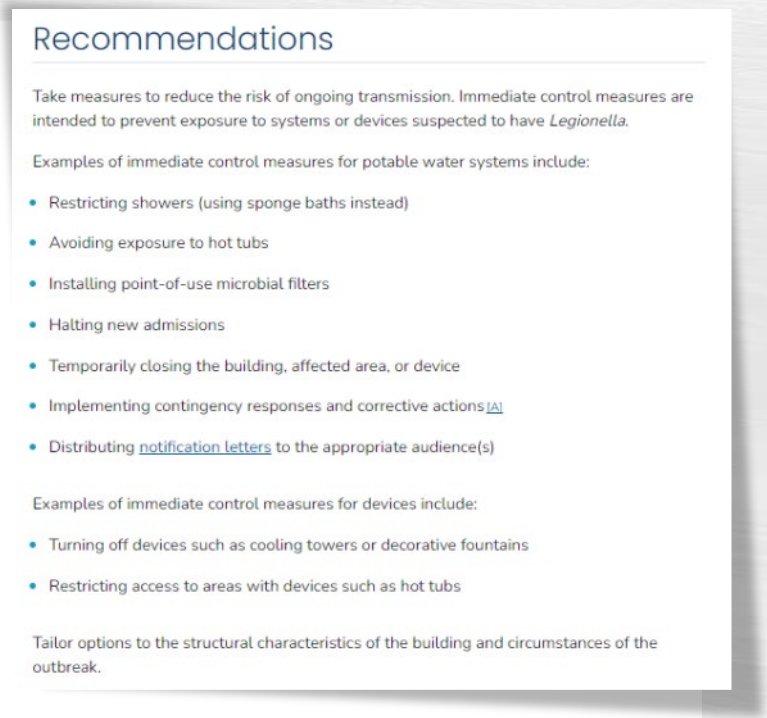
- **Lead service line replacement $1200-$12,500 per line**
- **NRDC estimates US replacement costs at $46-$56 billion**
- **Harvard School of Public Health study**
  - $9 billion in annual healthcare savings with replacement of US lead piping
  - $786 billion in healthcare savings over 35 years
- **Natural Resources Defense Council study**
  - 90% of savings from reduced cardiovascular disease
- **Infrastructure Investment and Jobs Act**
  - $15 billion for lead service line replacement
  - $11.7 billion toward Drinking Water State Revolving Loan Fund (DWSRF)

Source: Natural Resources Defense Council

Cost of Remediation

- **Consulting/Sampling**
  - Sampling $5,000-$30,000
  - Consulting costs $25,000-$100,000+
- **Water Restrictions**
  - Forced bottled water $1,000's per day
- **Point of Use Filters**
  - Up to $500 each, changed every 30-90 days
- **Disinfection and Treatment**
  - One-time treatment $8,000-$15,000
  - Supplemental treatment $50,000 - $200,000 per year
- **Infrastructure Changes - $M's**

****Not including cost of internal staff support, lost bookings/revenue, mitigating reputation**



Recommendations

Take measures to reduce the risk of ongoing transmission. Immediate control measures are intended to prevent exposure to systems or devices suspected to have *Legionella*.

Examples of immediate control measures for potable water systems include:

- Restricting showers (using sponge baths instead)
- Avoiding exposure to hot tubs
- Installing point-of-use microbial filters
- Halting new admissions
- Temporarily closing the building, affected area, or device
- Implementing contingency responses and corrective actions [A]
- Distributing notification letters to the appropriate audience(s)

Examples of immediate control measures for devices include:

- Turning off devices such as cooling towers or decorative fountains
- Restricting access to areas with devices such as hot tubs

Tailor options to the structural characteristics of the building and circumstances of the outbreak.

Financial Settlements & Liability

- **Public settlements $225,000 - $5,000,000 per complainant**
- **Settlement awards vary**
  - Severity of illness, death
  - Medical expenses
  - Lost wages
  - Pain and suffering, permanent disability
  - Financial earning power of decedent

- **Punitive damages for “negligence” or “willful misconduct”**
- **Worker’s Compensation Claims and Litigation**
- **Criminal Liability? Flint MI Officials Criminally Indicted**

Regulatory Fines & Orders

- **State Public Health Department**
  - Violations and fines for failure to comply
  - Ordered closure
- **OSHA (Occupational Hazards & Exposure)**
  - Violations Under General Duty Clause
  - Serious, Willful, Repeat
- **States/Cities with Public Health Ordinances/Regulations**
  - Failure to comply
  - Fines for failing to register

Review of Select Waterborne Contaminants

Water Exposure Routes

- **Ingestion**
  - Drinking contaminated water, or other fluids mixed with contaminated water
  - Eating food grown with contaminated water
  - Eating food washed with contaminated water
- **Inhalation**
  - Inhalation of contaminated aerosols
- **Aspiration**
  - Accidental choking and subsequent inhalation
- **Dermal**
  - Exposure through skin, eye, mucosa absorption

Source: Khalil et al. (2015)

Building Water System Hazards

Source: Centers for Disease Control & Prevention

Physical

- Scalding/Heat
- Sediment
- Particulates

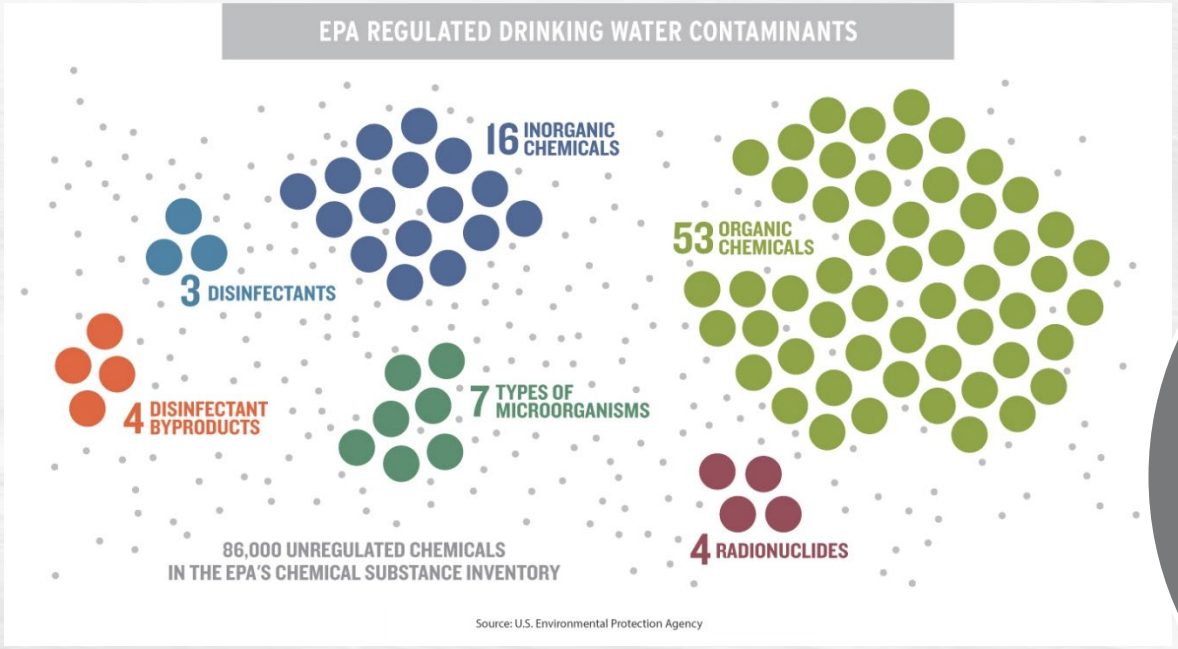
Chemical

- Disinfection By-Products (DBPs)
- Corrosion By-Products
- Fertilizers
- VOCs, semi-VOCs

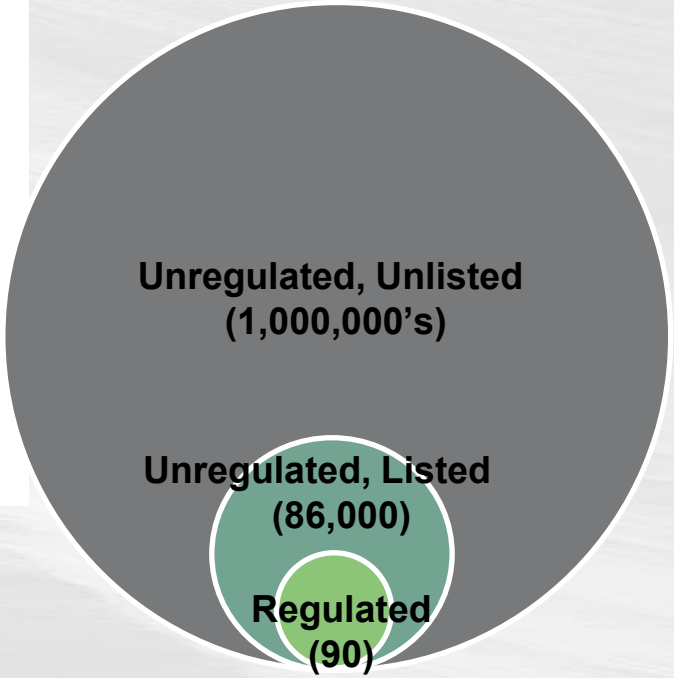
Biological

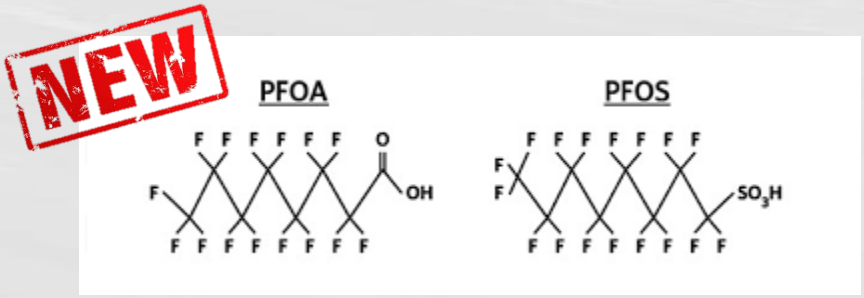
- Bacteria
- Viruses
- Fungi
- Protozoa

Regulated vs. Unregulated Contaminants



Source: U.S. Environmental Protection Agency





Opportunistic Pathogens

- **Immunocompromised most susceptible**
- **Legionella**
  - Aerosol inhalation, aspiration
  - Legionnaires' disease (Mortality rate up to 30%)
  - Pontiac Fever
  - Extrapulmonary Legionellosis
  - Complications from the above
- **Non-tuberculous Mycobacteria (NTM)**
  - Direct contact, inhalation
  - pneumonia, eye, wound, ear, soft tissue infections, sepsis
- **Pseudomonas**
  - Direct contact, person-to-person, inhalation
  - pneumonia, eye, wound, ear, soft tissue infections, sepsis

Source: Centers for Disease Control & Prevention

Source: QLabs

Source: QLabs

Bacteria Growth Risk Factors

Source: Centers for Disease Control & Prevention

Temperature:

- Growth Range = 68–120°F
- Ideal Growth Range = 77-113°F

Low/No Flow:

- Building Closure/Reduced Occupancy
- Dead Legs

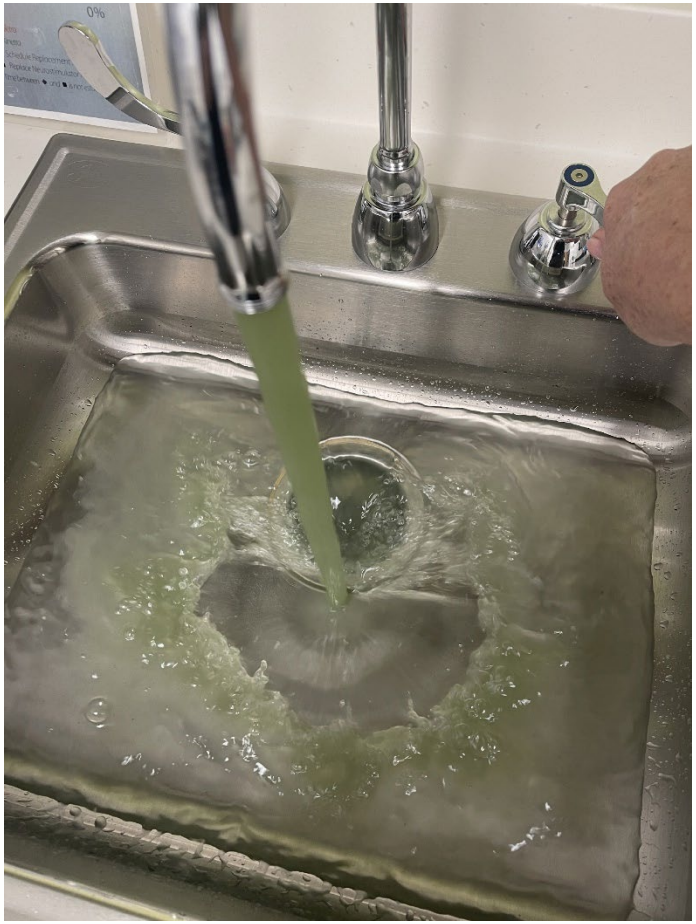
Low/No Disinfectant:

- Stagnant Conditions
- High Temps

Corrosion/Scale:

- Stagnant Conditions
- Biofilm Formation

Lead & Copper in Water



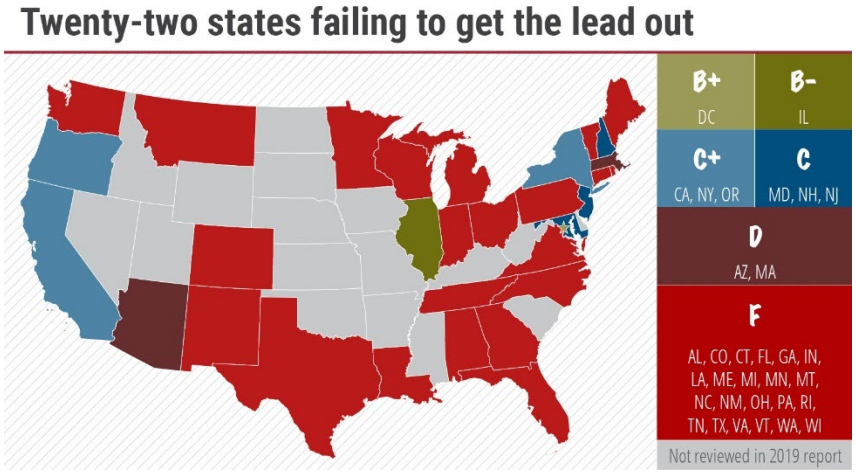
- **Estimated 9.2 million lead service lines still in place in US**
- **Lead (and copper) enters drinking water due to corrosion of plumbing materials that contain lead**
- **In 1986 EPA banned lead components in new construction**
  - Until 2014: “lead-free” contained up to 8% lead
  - Current 2020: ” “lead-free” contains 0.25% for fixtures/fittings, 0.2% for solder and flux

Lead & Copper in Water

- NRDC study found 56% of US population drank water from systems with detectable lead between 2018 and 2020.
- EPA estimates that 20% of lead exposure is due to exposure to water, up to 40-60% in formula-fed infants
- Buildings built before 1986 are more likely to have lead-containing components

Lead in School Water

- **US Government Accountability Office 2017 study**
  - 41% of school district, serving 12 million students, had not tested for lead in prior 12 months
  - 43% of school districts, serving 35 million students, had tested for lead
  - 37% of those districts that tested found elevated levels of lead
- **Public Interest Research Group**

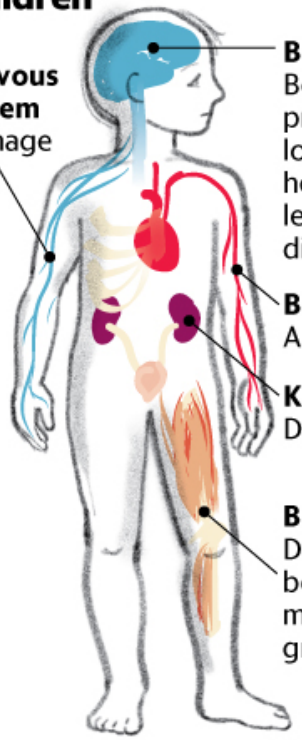


Source: Public Interest Research Group

Lead exposure

Although often without obvious symptoms, lead exposure can affect nearly every part of the human body. No safe level of lead in the bloodstream has been determined by the federal Centers for Disease Control and Prevention.

Children



Nervous system
Damage

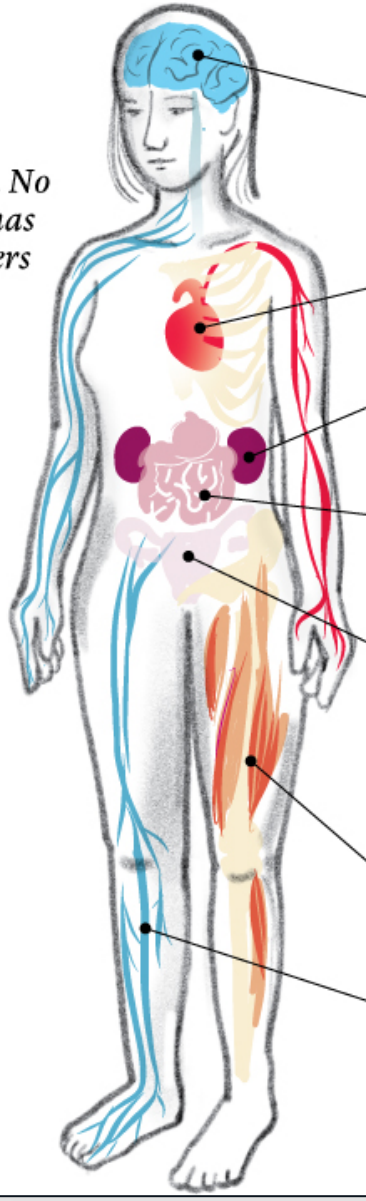
Brain
Behavior problems, lower IQ, hearing loss, learning disabilities

Blood
Anemia

Kidneys
Damage

Body
Decreased bone and muscle growth

Adults



Brain
Memory loss, lack of concentration, headaches, irritability, depression

Cardiovascular
High blood pressure

Kidneys
Abnormal function and damage

Digestive system
Constipation, nausea and poor appetite

Reproductive system
Men: Decreased sex drive and sperm count, sperm abnormalities
Women: Spontaneous miscarriage

Body
Fatigue, joint and muscle pain

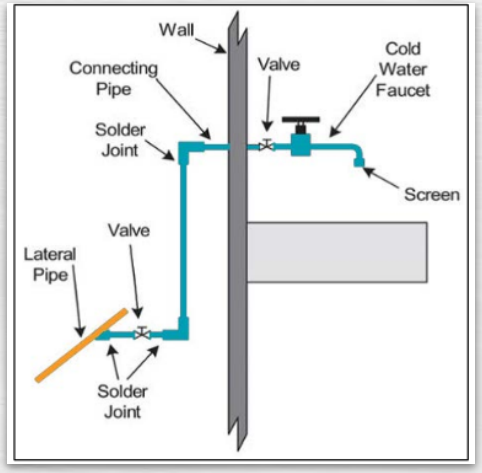
Nervous system
Damage including numbness and pain in the extremities

Sources: Centers for Disease Control and Prevention; National Institutes of Health

SHARON OKADA sokada@sacbee.com

Sources of Lead in Water

Source: U.S. Environmental Protection Agency



Source: U.S. Environmental Protection Agency

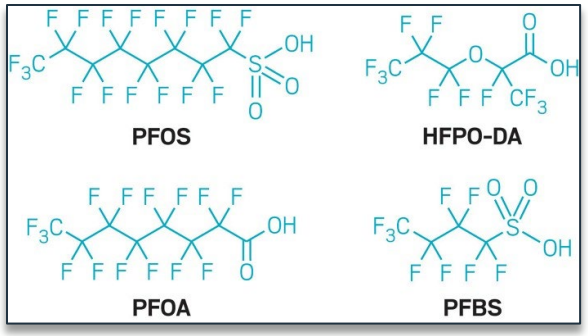
Source: National Sanitation Foundation

Disinfection Byproducts (DBPs)

- **Disinfection byproducts are generated when disinfectants are added to water**
- **Reaction between disinfectant (oxidant) and organic materials**
- **Regulated DBPs (MCLs and MCLGs established)**
  - trihalomethanes (THMs), haloacetic acids (HAA5), bromate, chlorite
  - Liver, kidney, and CNS effects, some studies show increased cancer risk
- **Unregulated DPBs**
  - nitrosamines, chlorate, haloacetonitriles, aldehydes, cyanides, haloniromethanes, etc.
  - Still being studied; some show increased cancer risk

Per- and Polyfluoroalkyl Substances (PFAS)

- Synthetic chemicals that are heat, water, and oil resistant
- "Miracle fire/flame retardants"
- Also widely used in clothing, carpet/upholstery, cookware, packaging, personal products, and firefighting foams
- Chemical structure makes them very stable and persistent
- Low levels of PFAS are found in blood of most humans, animals, plants
- Present in water, air, soil, surfaces, food
- Some studies show that harmful health effects can occur with long-term exposure
- EPA established MCL in 2024
  - PFOA/PFOS (4 ppt)
  - PFHxS, PFNA, HFPO-DA (10 ppt)



Water and the Future OEHS

Facts about Water

Water is a "universal solvent" – it dissolves more substances than any other liquid

~85 gallons of water used per person per day

20-25 % of global water demand to increase by 2050

0.8-1.3 gallons of water the average human drinks per day

Facts about Water

Water is critical to human health and all life on Earth

97% of the Earth's water is undrinkable

2% of the Earth's water is locked in permanent ice caps & glaciers

Increase in watersheds facing variability/less predictable water supplies **19%**

51 countries predicted to have extreme water stress by 2050

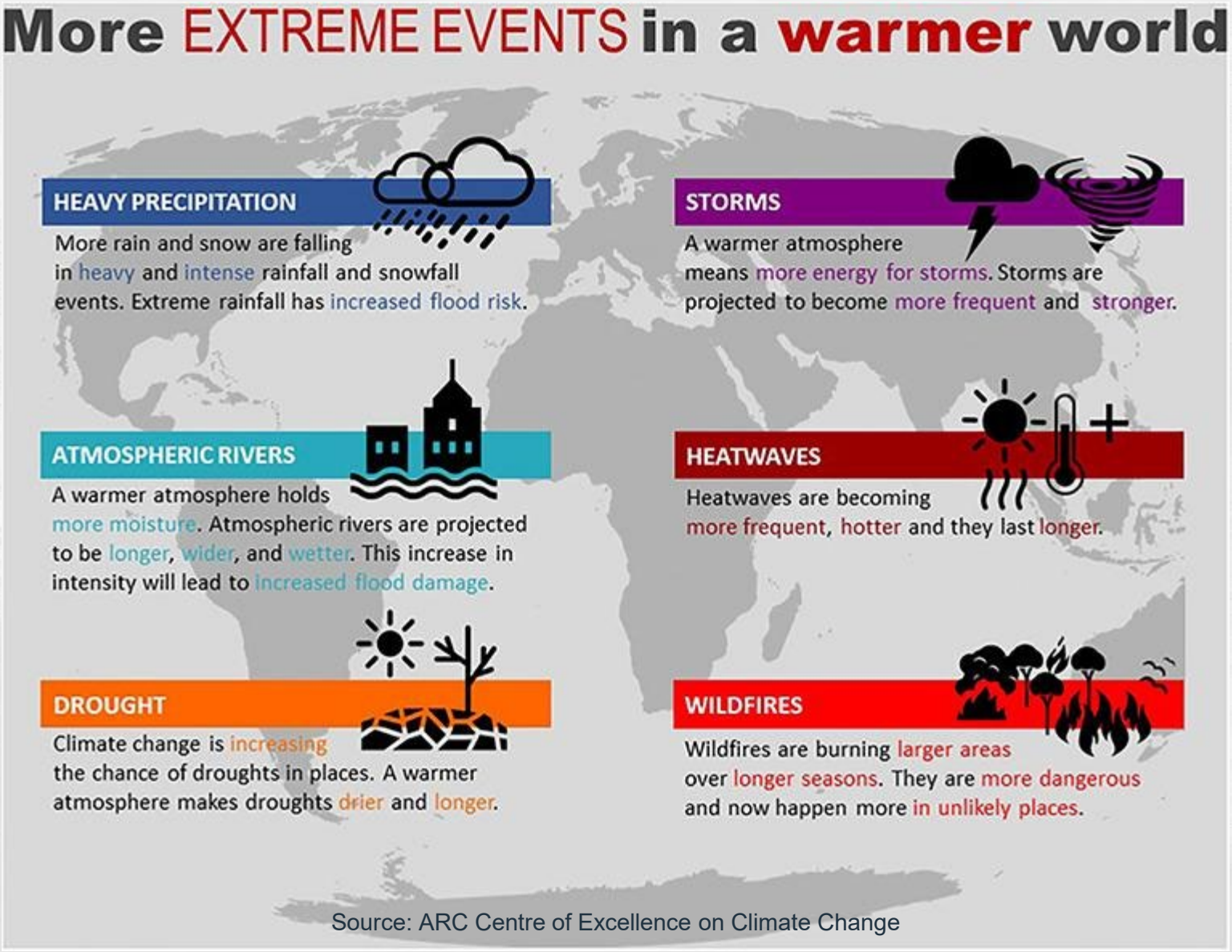
50% of World's largest cities are already experiencing water scarcity

700 Million people could be displaced due to extreme water scarcity by 2030

Impacts of Climate Change

- Earth's temperature has increased 0.11°F (average) per decade since 1850 (2 ° F total)
- Ten warmest years in historical record have occurred in the past decade (2014-2023)
- 2023 was the warmest year since global records began in 1850
  - 2.12°F above the 20th Century average (57.0°F)
  - 2.43°F above the pre-industrial average (1850-1900)
- It has been 47 years since Earth has had a colder than average year

More EXTREME EVENTS in a warmer world



Source: ARC Centre of Excellence on Climate Change

Climate Change and Water Quality

- **Water Scarcity/Shortages**
  - Most immediate concern
  - Lack of sufficient access to water leads to death and illness
  - Low water levels result in concentrated contaminants (salts, bacteria, chemicals)
  - Lower water levels lead to warmer water (increased bacteria growth)
  - Low water levels result in low water pressures, which strain treatment plants
  - Droughts require farmers to use more irrigation water, leading to increased runoff (pesticides, fertilizers)

Source: Stockholm International Water Institute

Climate Change and Water Quality

Extreme Cold

Pipe bursts

Infrastructure damage

Contaminant entry

Photos: FACS or Public Domain

Climate Change and Water Quality

Extreme Hot

Microorganism growth

Increased dissolved materials

Increased salinity

Photos: FACS or Public Domain

Climate Change and Water Quality

Hurricanes, etc.

- Stormwater and sewer overflows
- Increased contamination from stormwater runoff

- Reduced ability to treat water due to outages, fires
- Damage to infrastructure

Photos: FACS or Public Domain

Climate Change and Water Quality

Wildfires

- Damage to infrastructure
- Thermal degradation of pipes

- Backflow from loss of pressure, strain on water system

- Loss of vegetation leads to increased leaching into groundwater
- Increased runoff, concentrated contaminants

- Influx of chemicals from fire damage, burned materials; may not be filtered by typical PWS

Photos: FACS or Public Domain

Climate Change and Water Quality

- **Potential Contaminants from Hurricane and Wildfire Impact**
  - Heavy metals (lead, cadmium, chromium, etc.)
  - VOCs (BTEX, chlorobenzene, methylene chloride, styrene, vinyl chloride…)
  - Semi-VOCs (phenol, naphthalene, nitrobenzene, 1,4-dioxane, phthalates…)
  - PAHs (benzo(a)pyrene, fluorene, anthracene)
  - Plastics and microplastics
  - Per- and poly-fluoroalkyl substances (PFAS)
  - Particulate, sediment, ash, char
- **Many of these contaminants are not regulated and do not have to be tested to deem water quality "safe" for potable use**

How Can IHs Get Involved?

- **"We Don't Do Water"… but we should!**
- **IHs are uniquely positioned!**
  - We know exposure and risk assessment!
  - Different medium, sometimes different agents
- **What can an IH do? Start "doing water"**
  - Learn about water/plumbing systems
  - Understand how contaminants enter and persist water systems
  - Help your clients, businesses to evaluate risk
  - Educate others, help to generate or review industry guidance
  - Participate in discussions on how to mitigate risks
  - Encourage your community to plan for water quality impacts
  - Be a voice for planning to address the issues and at-risk populations

Thank You!

Megan Canright Racicot, MPH, CIH
megan.canright@facs.com
858-247-1050

Right People.

Right Perspective.

Right Now.