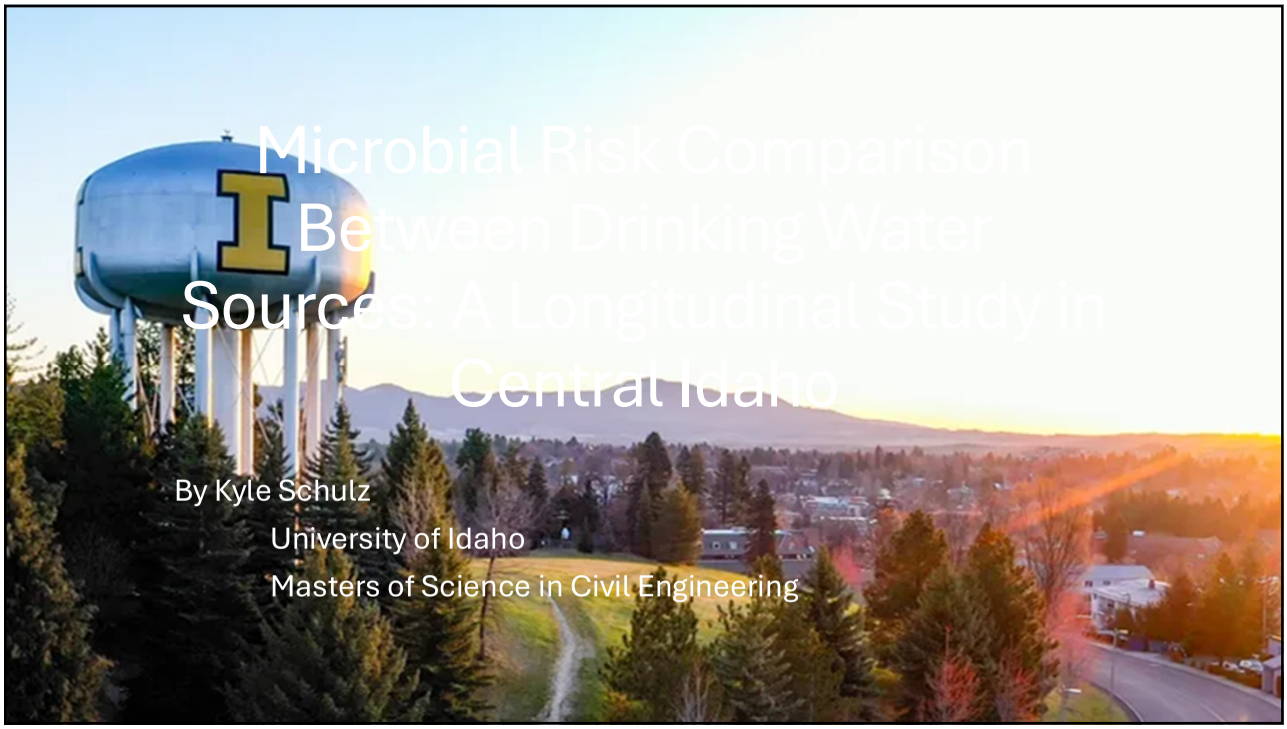

Microbial Risk Comparison Between Drinking Water Sources: A Longitudinal Study in Central Idaho
By Kyle Schulz
University of Idaho
Masters of Science in Civil Engineering

1

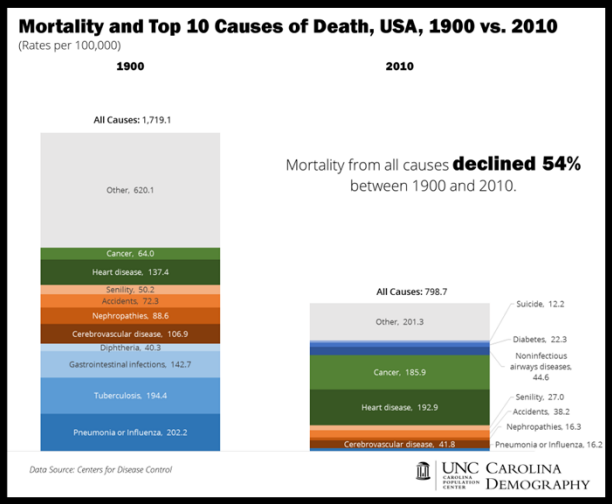

Waterborne Illness History in the USA

2

Historical Waterborne Disease

1900s: Waterborne illness was widespread, being the third leading cause of death in 1900

Major Pathogens: Largely gastrointestinal
- Bacterial:
  - *Vibrio cholerae*: Cholera
  - *Salmonella enterica*: Typhoid fever
- Protozoan:
  - *Giardia*: Giardiasis
  - *Cryptosporidium*: Cryptosporidiosis



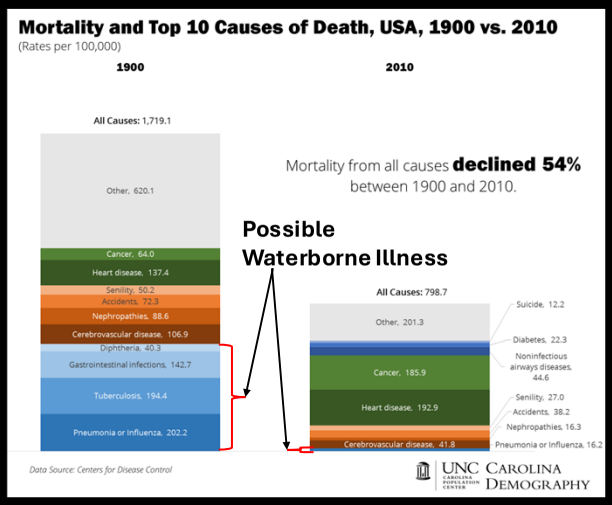
US Mortality Rates

3

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US Mortality Rates

4

Safe Drinking Water Act (1974): Two rules

Surface Water Treatment Rule (SWTR):

- Log-removal of *Cryptosporidium* (2), *Giardia* (3), and viruses (4)
  - Filtration
  - Disinfection
- Chlorine residual of 0.2mg/L

Ground Water Rule (GWR):

- Only needs to achieve safe water quality standards
  - Nonprescriptive
- Requires utilities providing water to 3,300 to monitor water quality for contamination

5

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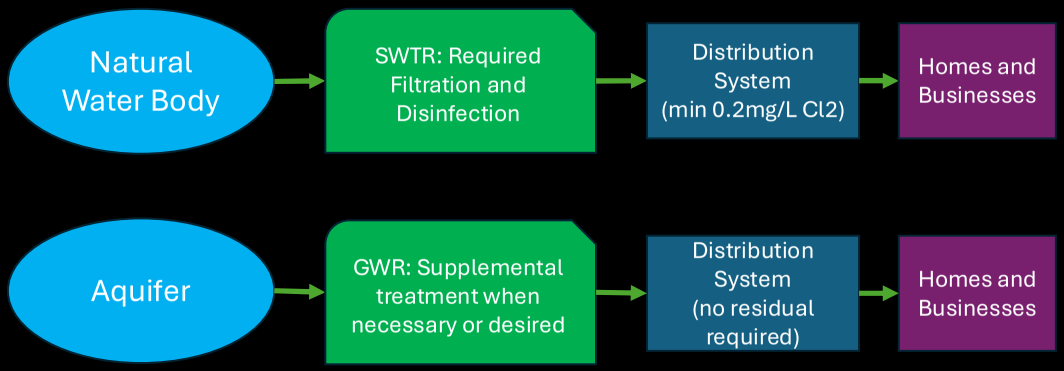
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Current Management Strategies Assume Source Water is the Primary Driver of Risk

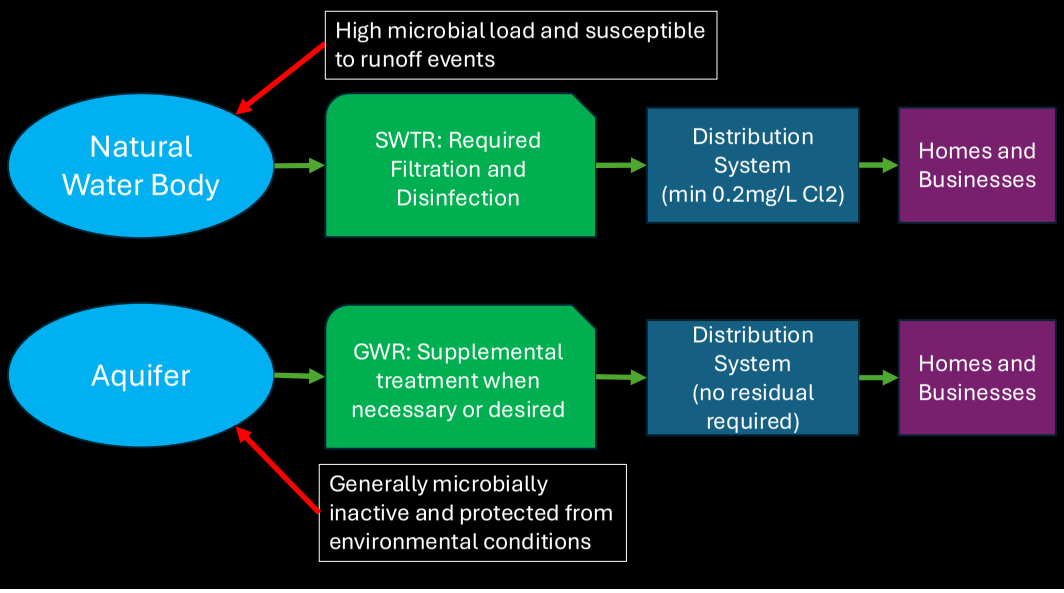
6

Typical Public Water Systems and Treatment



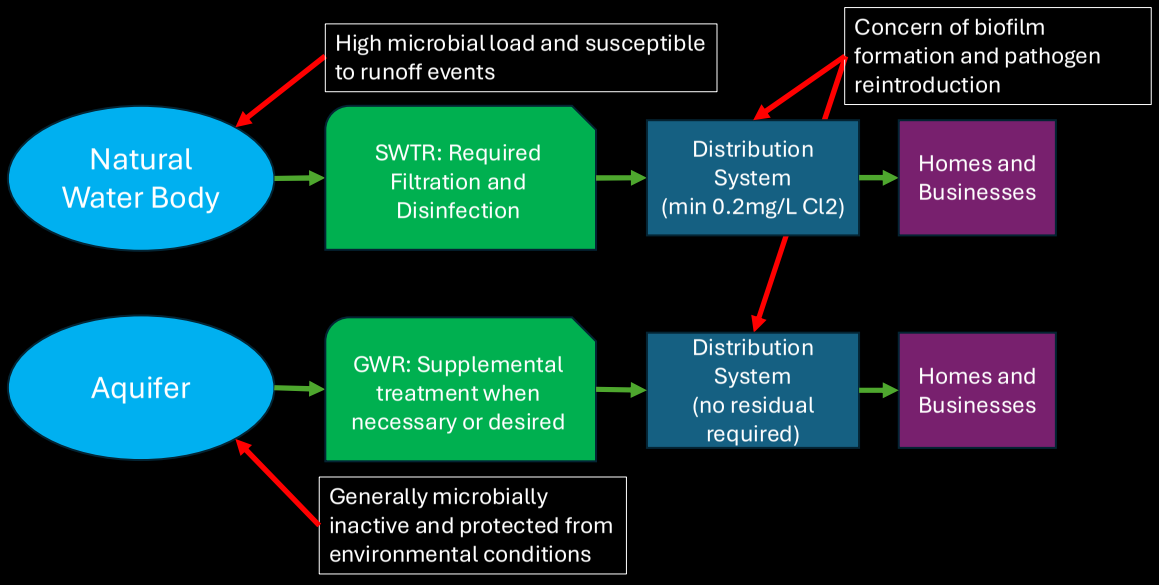
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Typical Public Water Systems and Treatment



8

Typical Public Water Systems and Treatment

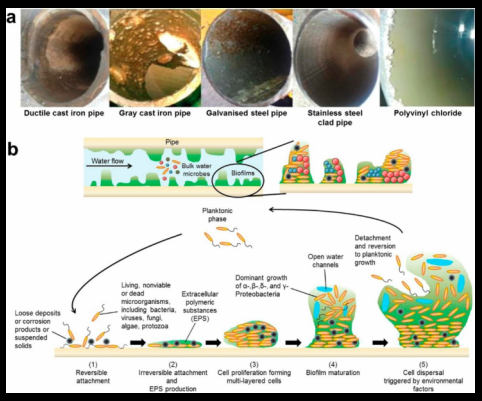


9

Modern Threat: Opportunistic Pathogens

US Annual Waterborne Disease:
- 7.15 million illnesses
- 118,000 hospitalizations
- $3.33 billion in cost

Primarily caused by biofilm related pathogens
- Chlorine resistant
- Present in the natural environment



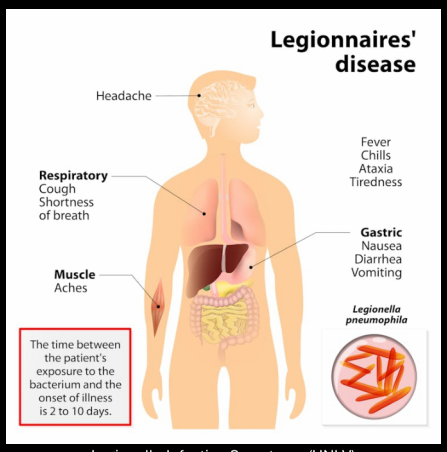
Biofilm formation in a pipe (Liu et al., 2016)

10

Modern Threat: Opportunistic Pathogens

Bacterial Threats:
- *Legionella*: Legionnaire's Disease
- Nontuberculous *Mycobacterium* (NTM)
- *Pseudomonas*

Primary infection vector: Inhalation of steam and aerosolized bacterial particles
- Outbreaks are often linked to cooling towers and showers
- Especially harmful for immunocompromised individuals



Legionella Infection Symptoms (UNLV)

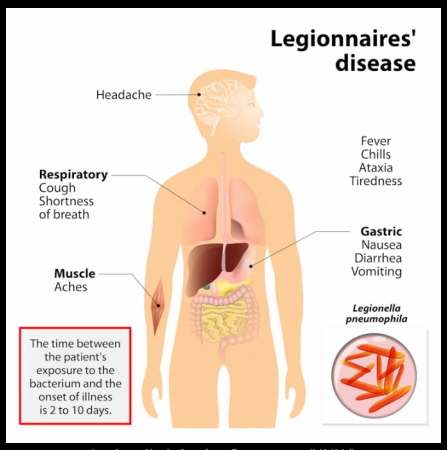
11

Modern Threat: Opportunistic Pathogens

Bacterial Threats:
- *Legionella*: Legionnaire's Disease
- Nontuberculous *Mycobacterium* (NTM)
- *Pseudomonas*

Unregulated by the EPA, assumed to be found in the natural environment

Primary infection vector: Inhalation of steam and aerosolized bacterial particles
- Outbreaks are often linked to cooling towers and showers
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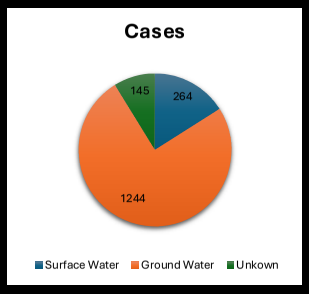

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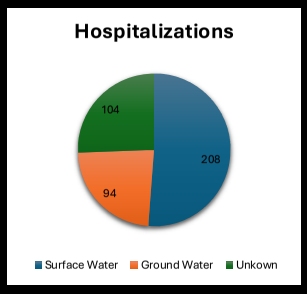
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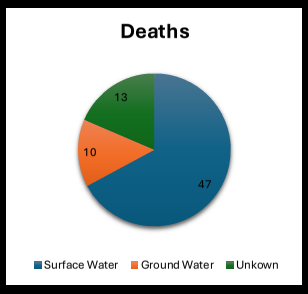
Modern Threat: Opportunistic Pathogens

2015-2020 CDC Reports:

- Many illnesses found to be linked to opportunistic pathogens
- Found many cases and hospitalizations stemming from groundwater-sourced systems







13



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Overall Goals

1. Compare the source water quality and treatment performance of two public water systems (PWS), one surface water (SW) and one ground water (GW).
2. Analyze how water quality and pathogen presence may change throughout a distribution system in response to system management practices.
3. Quantify the pathogenic risk of each system and how it may change throughout the year.

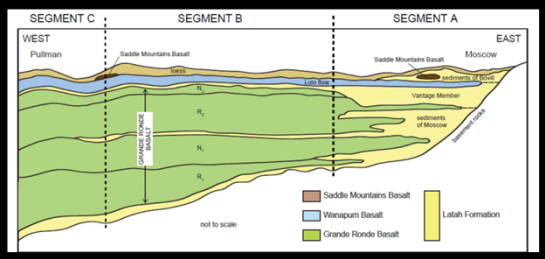
15

Study Design: Choice of systems

SW System: Lewiston, Idaho
- Population: 34,500
- Primary sources is the Clearwater river
- Supplementary water from wells



GW System: Moscow, Idaho
- Population: 25,700
- Source: Palouse Basin Aquifer
- Two primary wells with a couple supplementary wells



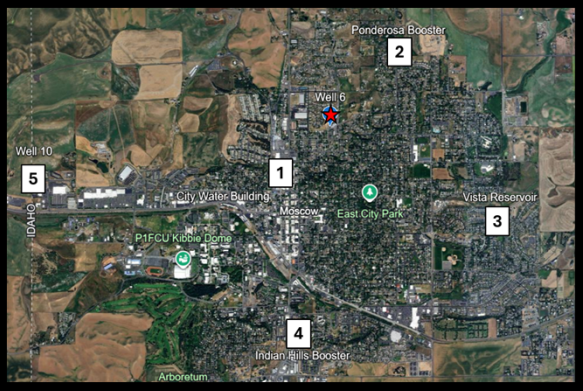
16

Study Design: Sample Locations

12-Month study with samples taken monthly from each location



Lewiston, ID (SW)

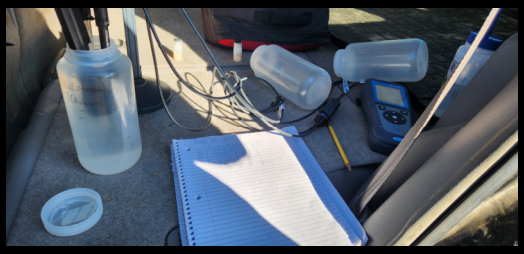


Moscow, ID (GW)

17

Study Design: Water quality parameters

Physical and Chemical Parameters: Alkalinity, pH, chlorine residual, temperature, conductivity, oxidative reduction potential (ORP), dissolved oxygen



Biological Parameters:

- Heterotrophic plate counts (HPC)
- V4 16S rRNA Sequencing

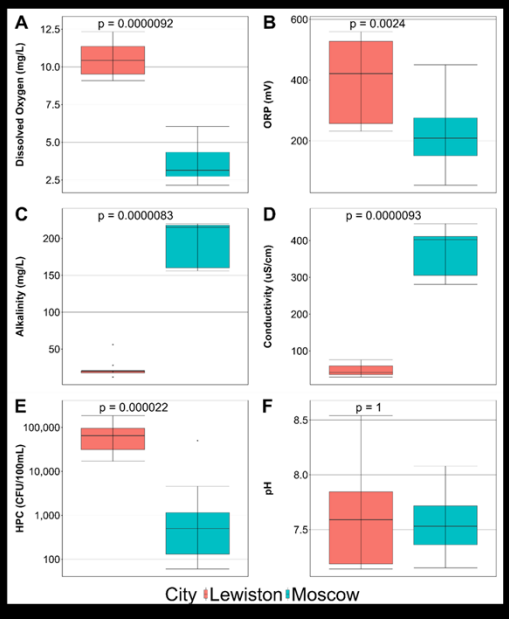


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General Source Water Quality





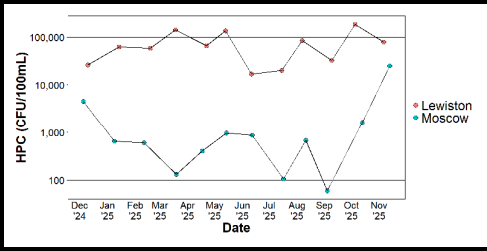


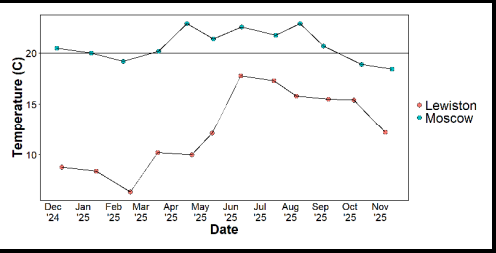
20

Temporal Trends

Seasonal Trends:

- Moscow (GW): Consistent temperatures and microbial loading throughout the year.
- Lewiston (SW): High microbial loads throughout the winter with expected temperature variations.





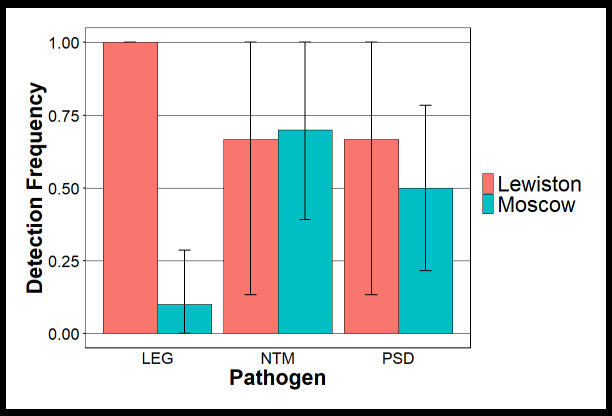
21

Source Pathogen Detection Rates

Legionella:

- 1/10 detection rate in Moscow (GW)
- 3/3 detection rate in Lewiston (SW)

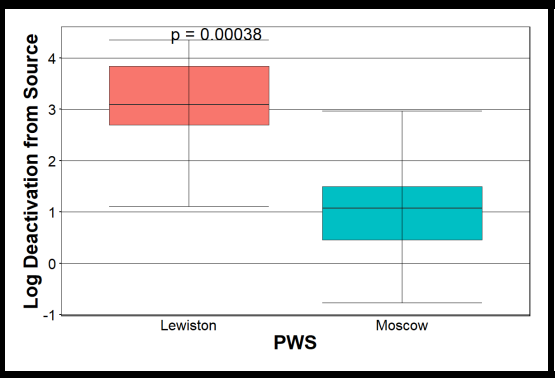
Pseudomonas and NTM were found at comparable detection rates in both systems

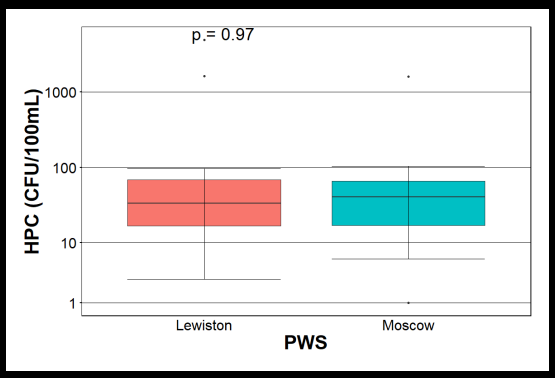


22

Treatment Performance

The surface treatment was able to reduce HPC levels to an equivalent level as the groundwater system



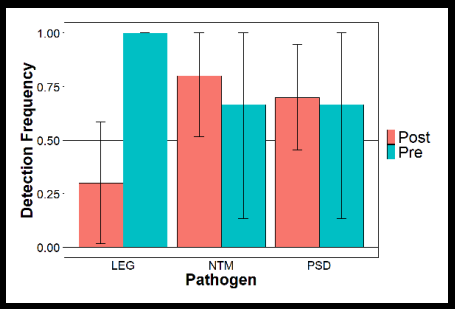


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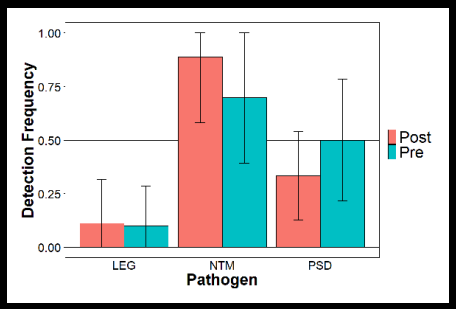
Treatment Performance

Lewiston (SW): Able to reduce Legionella detection rates to 30% of samples.

Moscow (GW): Saw little difference between detection rates.



Surface Water Plant



Groundwater Well

24

Key Takeaways

1. While Lewiston's surface water plant did experience higher microbial loading and overall pathogen detection rates, it was able to reach a similar water quality as compared to Moscow.

25



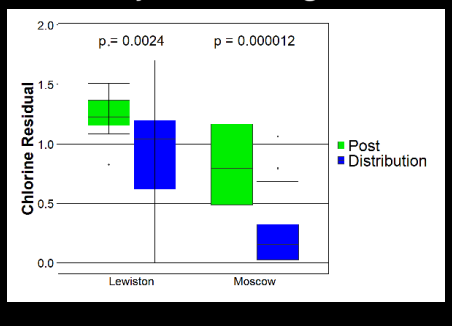
26

Chlorine Residual: Average and targets

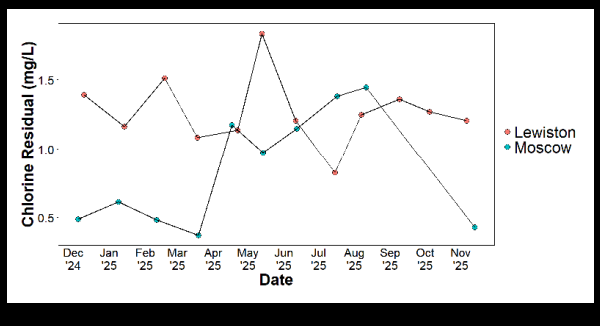
Surface Water System:
- Consistent target of around 1.25mg/L
- Rarely dropped below 0.5mg/L in the distribution system

Groundwater System:
- Seasonal target near 1.25mg/L in the summer, 0.5m/L in the winter
- Often dropped to undetectable levels in the distribution system

System Average



Residual After Treatment



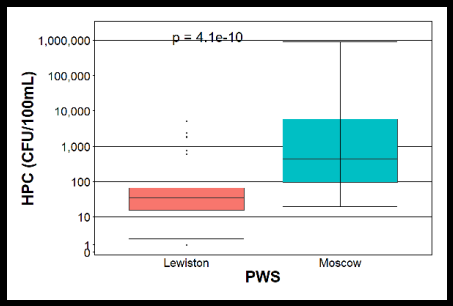
27

HPC and Log-growth

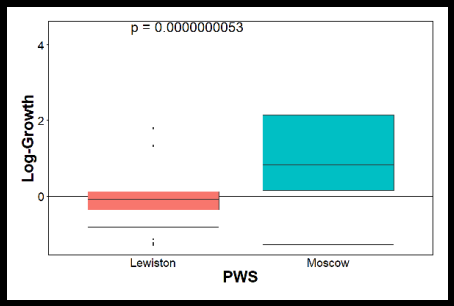
Surface Water System:
- Average: 283CFU/100mL
- Log-growth of slightly below zero

Groundwater System:
- Average: 30,752CFU/100mL
- Average log regrowth of 1, with 25% of samples over 2

Distribution Average

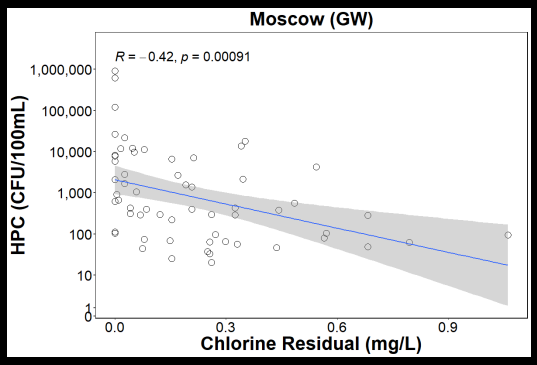


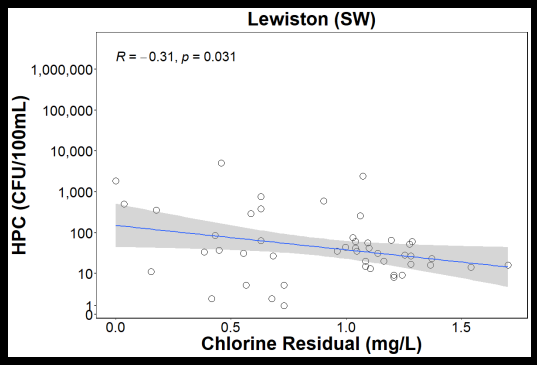
Log-Growth



28

Chlorine Correlation with HPC





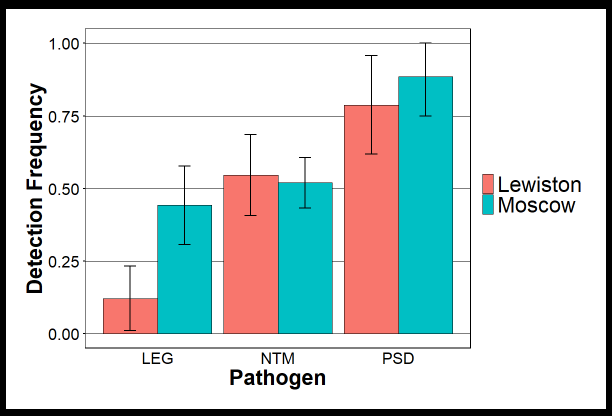
29

Pathogen Detection Rates

Legionella: Much higher detection rate in the groundwater system as compared to the surface water system

Pseudomonas and NTM: Similar detection rates

Distribution Detection Rates



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Key Takeaways

1. While Lewiston's surface water plant did experience higher microbial loading and overall pathogen detection rates, it was able to reach a similar water quality as compared to Moscow.

2. Opportunistic pathogens such as *Legionella*, *Pseudomonas*, and NTM were detected at similar rates in each distribution system. *Legionella* was also found in a much higher percentage of distribution samples in Moscow, regardless of its presence in the source aquifer.

31



32

Method: Mechanistic inhalation risk

Assumptions:
- Measures inhalation risk from showering
  - Using breathing rate and shower time from the EPA
- Assumes no increase in risk through premise plumbing

$$C_{Path} = 10{,}000 * HPC * \sum_{i=1}^{n} RA_i$$

$$Dose = C_{Path} Bt \sum_{i=1}^{10} C_{aer,i} V_{aer,i} \sum_{j=1}^{10} F_j D_j$$

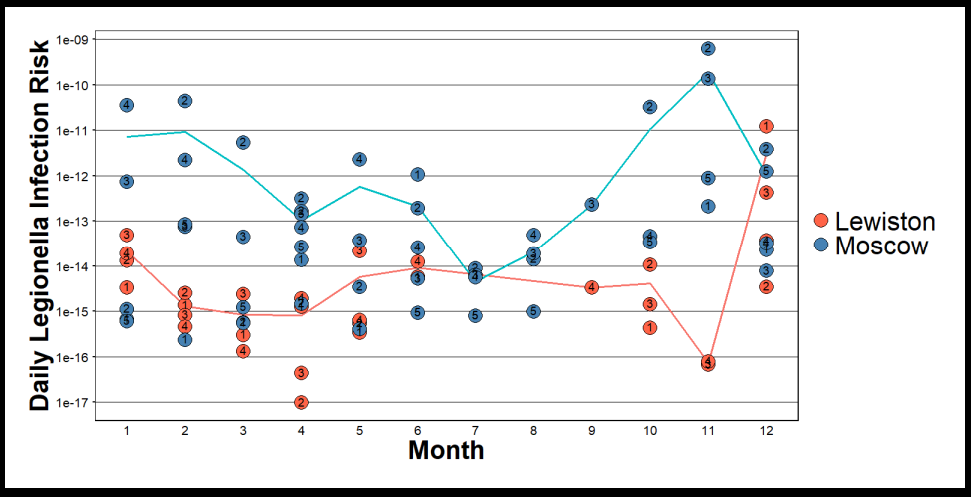
$$P_{inf,daily} = 1 - e^{-r*Dose}$$

EPA risk standard is 1/10,000 risk per year
- Converts to roughly a one in ten million daily risk



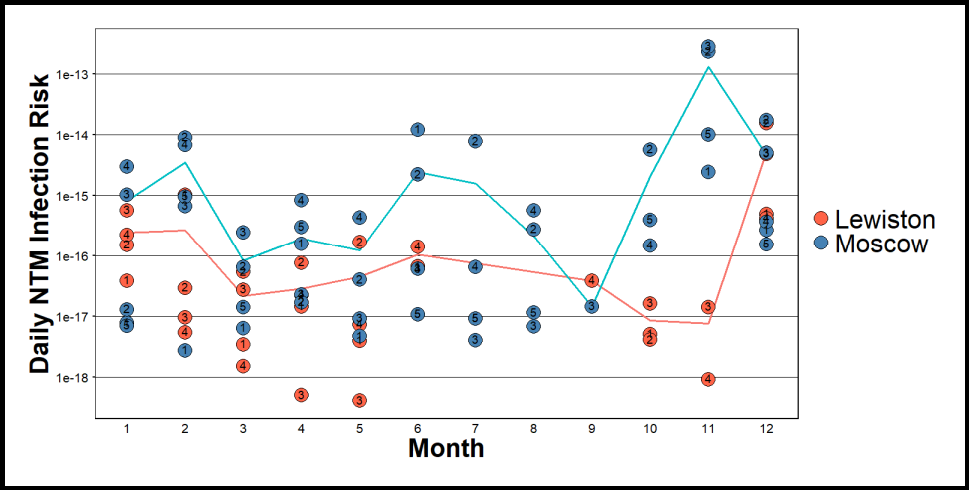
33

Legionella Infection Risk



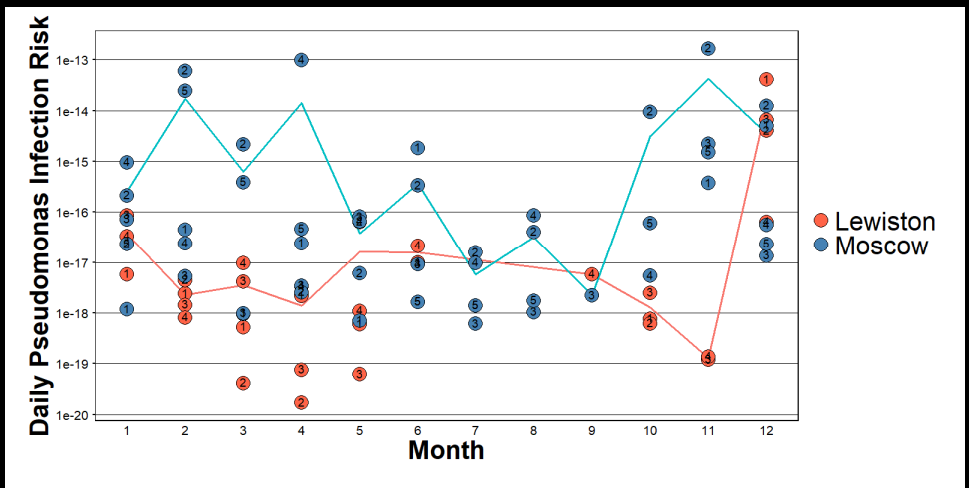
34

NTM Infection Risk



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Pseudomonas Infection Risk



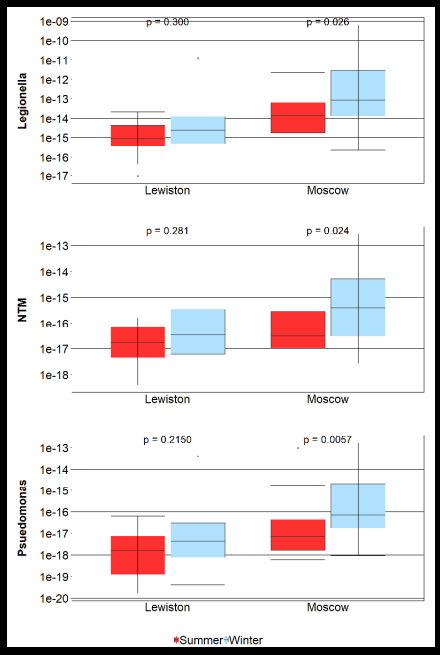
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Seasonal Variation

Moscow's system experienced a significant increase in pathogenic risk in the winter

- Directly correlates with the period of low chlorine residual

Lewiston's surface water system experienced similar risk regardless of the season



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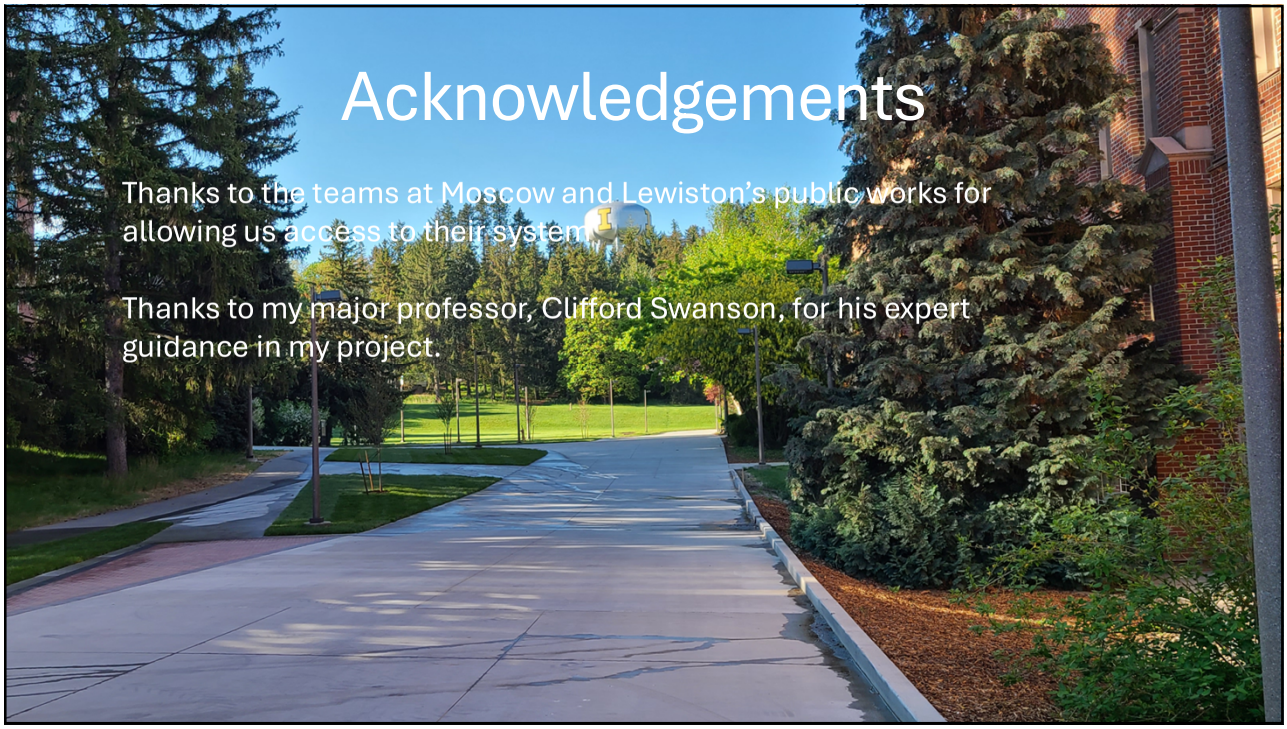
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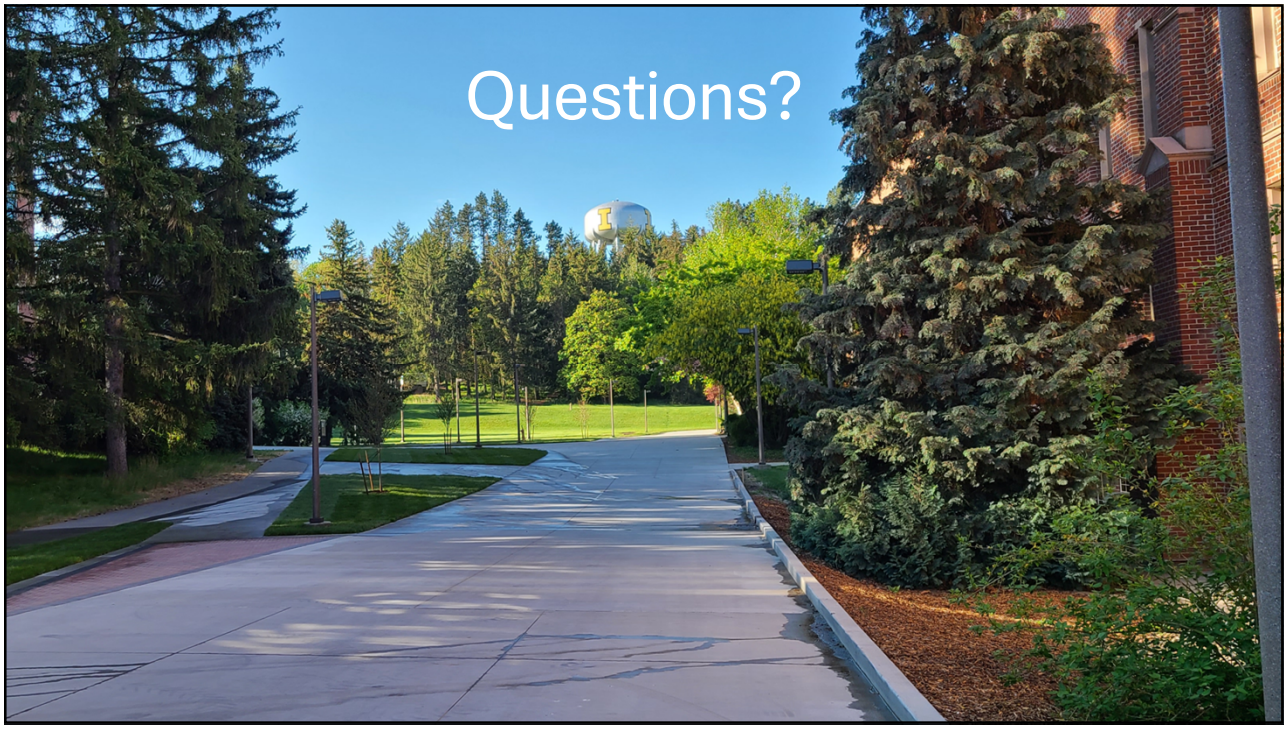
2. Opportunistic pathogens such as *Legionella*, *Pseudomonas*, and NTM were detected at similar rates in each distribution system. *Legionella* was also found in a much higher percentage of distribution samples in Moscow, regardless of its presence in the source aquifer.

3. Pathogenic risk appears to correlate directly with the differing management practices, particularly with response to differing chlorine residual targets.

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Acknowledgements
Thanks to the teams at Moscow and Lewiston's public works for allowing us access to their system.
Thanks to my major professor, Clifford Swanson, for his expert guidance in my project.

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Questions?

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