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# Premise Plumbing Materials and Opportunistic Premise Plumbing Pathogen Growth



*Director of  
Water Safety  
and  
Management*

Special  
Pathogens Lab,  
a Pace  
Laboratory

Abraham Cullom, PhD

For more information:

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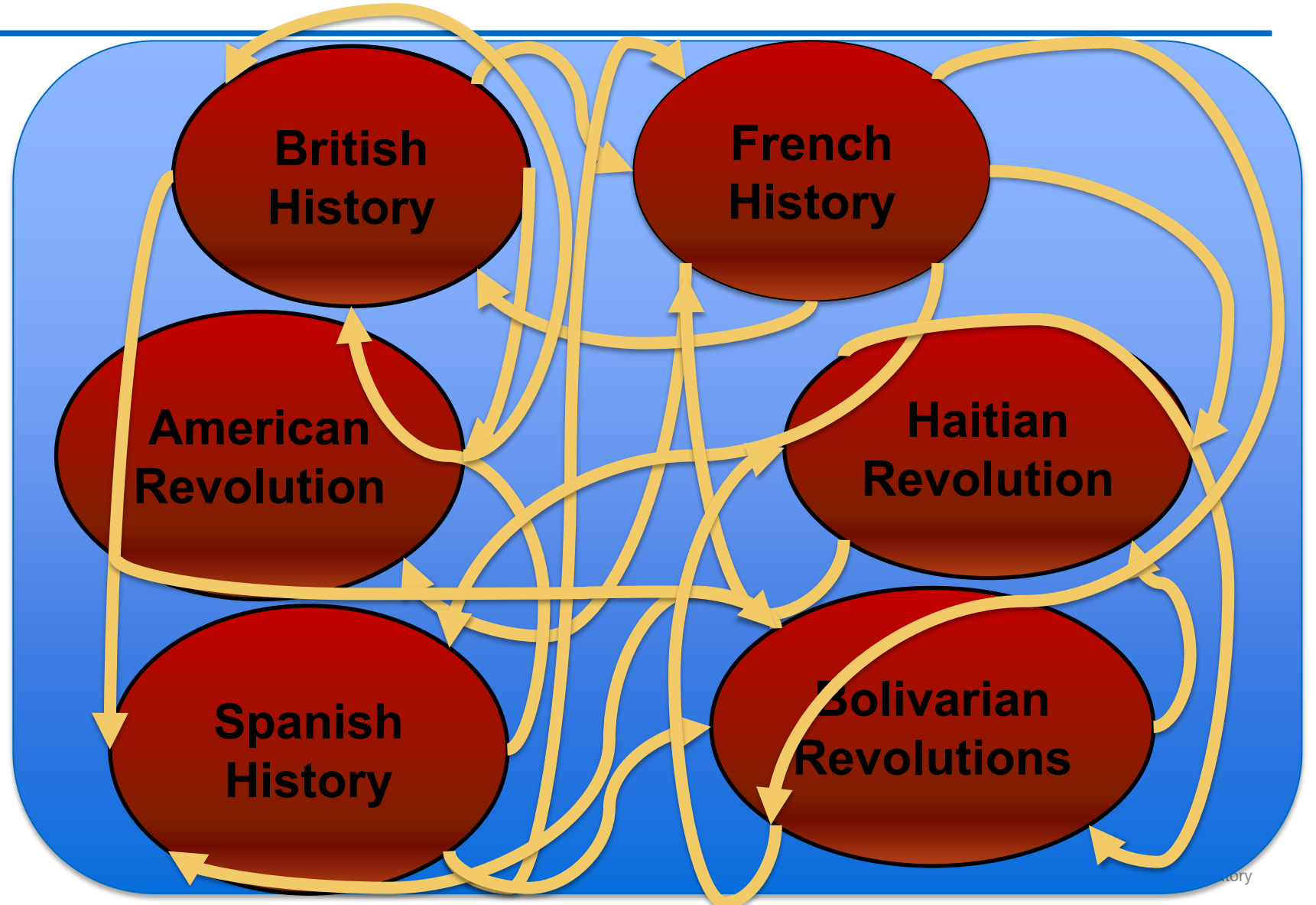
*Review*

# Critical Review: Propensity of Premise Plumbing Pipe Materials to Enhance or Diminish Growth of *Legionella* and Other Opportunistic Pathogens

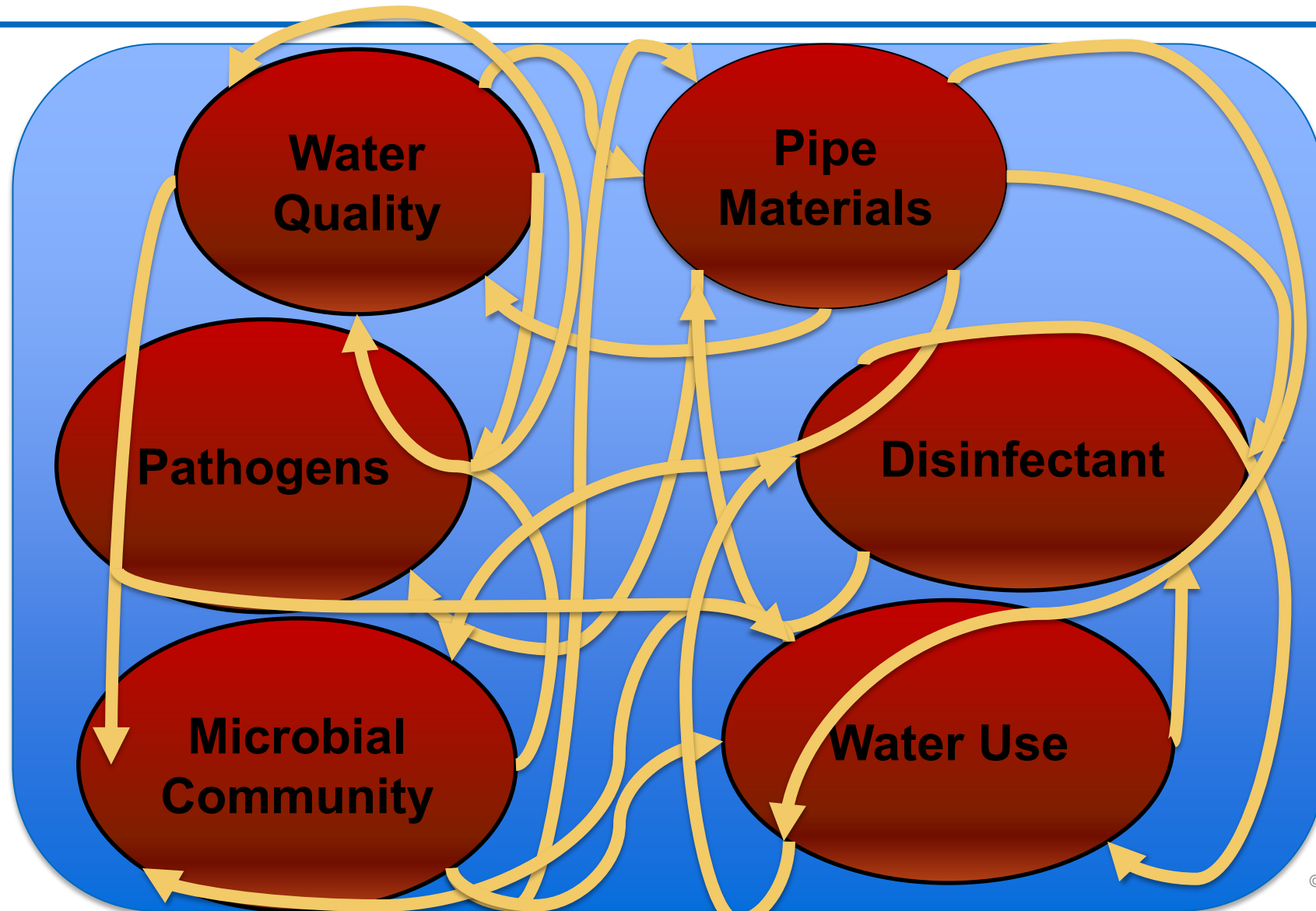
Abraham C. Cullom <sup>1</sup>, Rebekah L. Martin <sup>1,2</sup> , Yang Song <sup>1</sup>, Krista Williams <sup>3</sup>,  
Amanda Williams <sup>4</sup>, Amy Pruden <sup>1</sup>  and Marc A. Edwards <sup>1,\*</sup>

# Understanding Early Modern History

## Spaghetti & Meatball System



# Understanding In-Building Plumbing



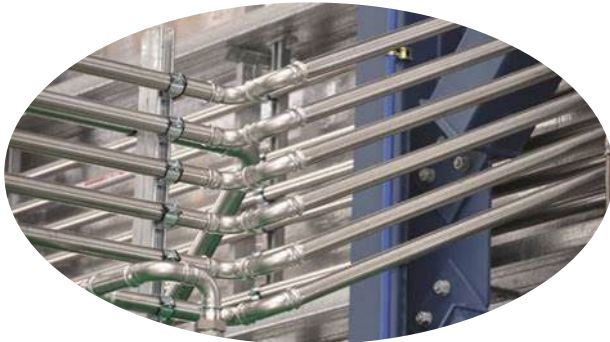


# Roadmap

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## RE-EXAMINE RULES OF THUMB

- Plastic: Microbial food source
- Iron: Important nutrient
- Copper: Microbe killer



## IMPORTANT & NOVEL INTERACTIONS

- Disinfectant effects
- Water temperature
- Microbial ecology
- Antibiotic resistance

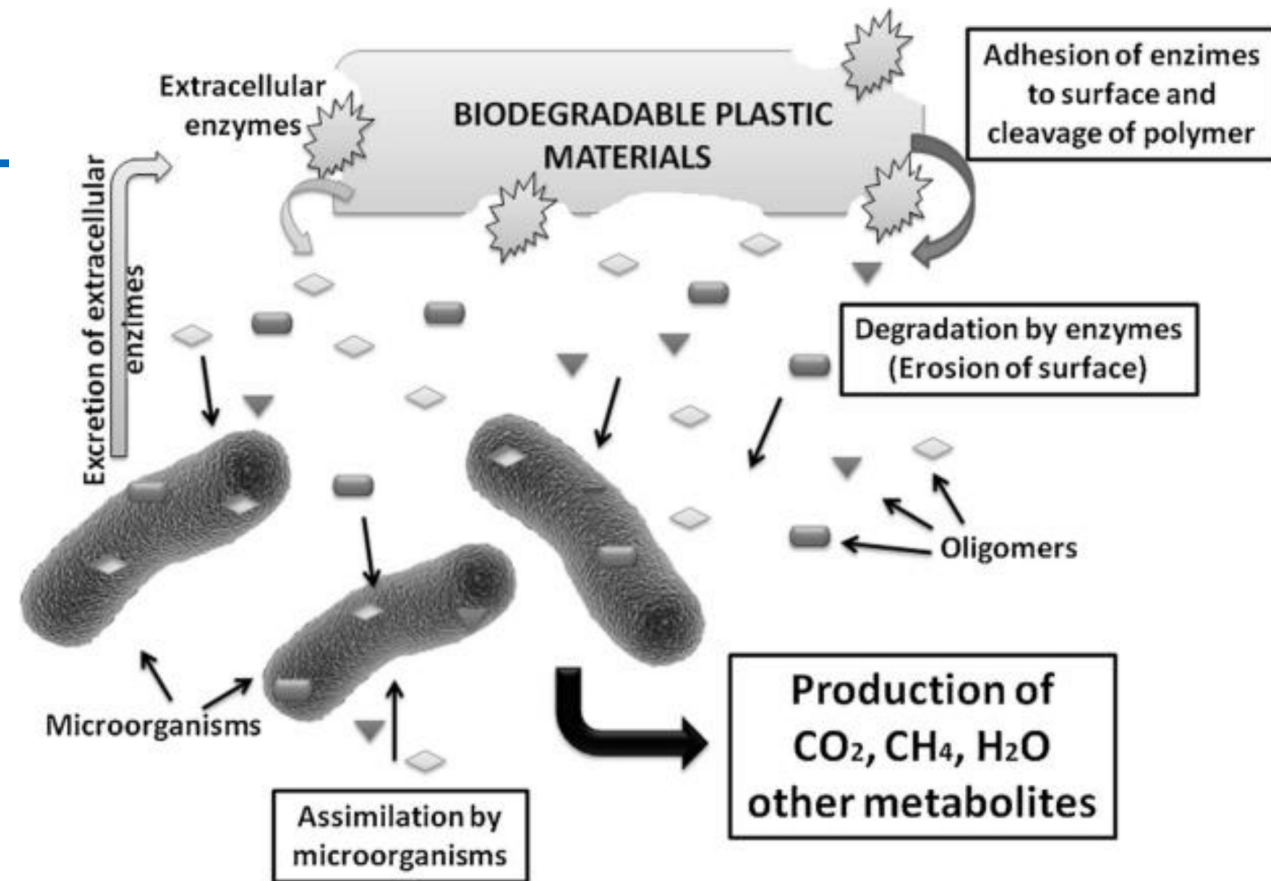


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# **RULE OF THUMB: PLASTIC IS MICROBIAL FOOD**

# Leaching organic carbon

- Nutrients for microbial growth
- Both primary polymer and additives (e.g., flexibilizers)
- In new pipes,  $\uparrow$  *Legionella* growth
- **Differences in plastic type**
- **Time-dependent**

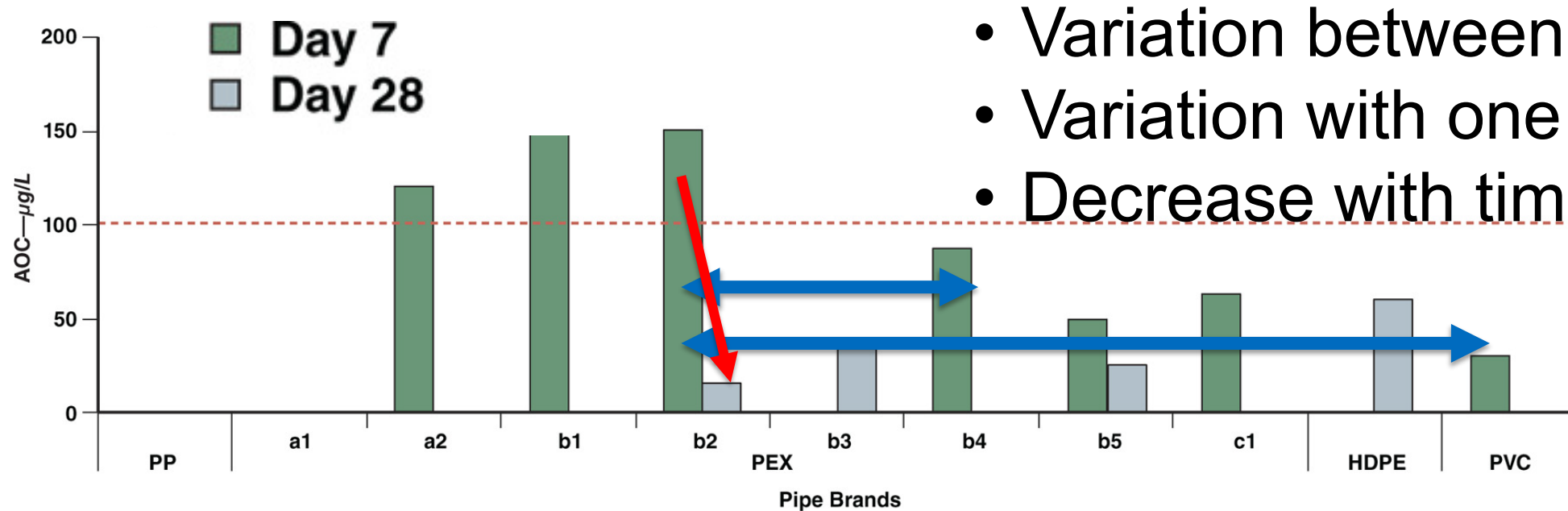


J. Shrestha, J. Li. Influence of permeate from domestic reverse osmosis filters on lead pipes corrosion and plastic pipes leaching. *Journal of Water Process Engineering*, 2017  
Learbuch, K.L.G.; Lut, M.C.; Liu, G.; Smidt, H.; van der Wielen, P.W.J.J. Legionella growth potential of drinking water produced by a reverse osmosis pilot plant. *Water Res.* **2019**, *157*, 55–63.

Figure: Liu D, Zhao P, Chen J, Yan Y, Wu Z. Recent Advances and Applications in Starch for Intelligent Active Food Packaging: A Review. *Foods*. 2022; 11(18):2879. <https://doi.org/10.3390/foods11182879>



# Carbon release variable with **time** and **type**!



- Variation between pipe materials
- Variation with one pipe material
- Decrease with time

AOC—assimilable organic carbon, HDPE—high-density polyethylene, PEX—cross-linked polyethylene, PP—polypropylene, PVC—polyvinyl chloride

Water utilities in the United States have concluded that AOC drinking water levels >100 µg/L at water temperatures >15°C greatly increase the probability of coliform occurrences. This experiment was conducted in the absence of disinfectant.

Connell, M., Stenson, A., Weinrich, L., LeChevallier, M., Boyd, S.L., Ghosal, R.R., Dey, R. and Whelton, A.J. (2016), PEX and PP Water Pipes: Assimilable Carbon, Chemicals, and Odors. Journal - American Water Works Association, 108: E192-E204.

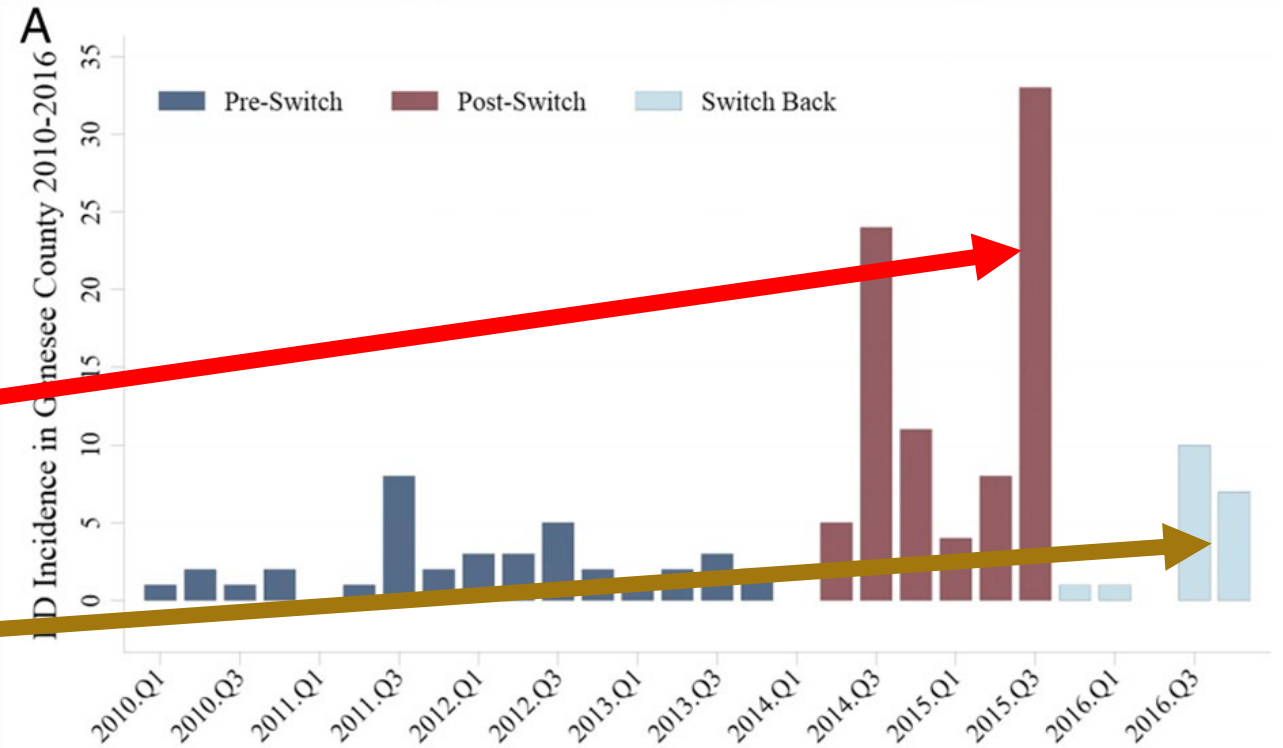
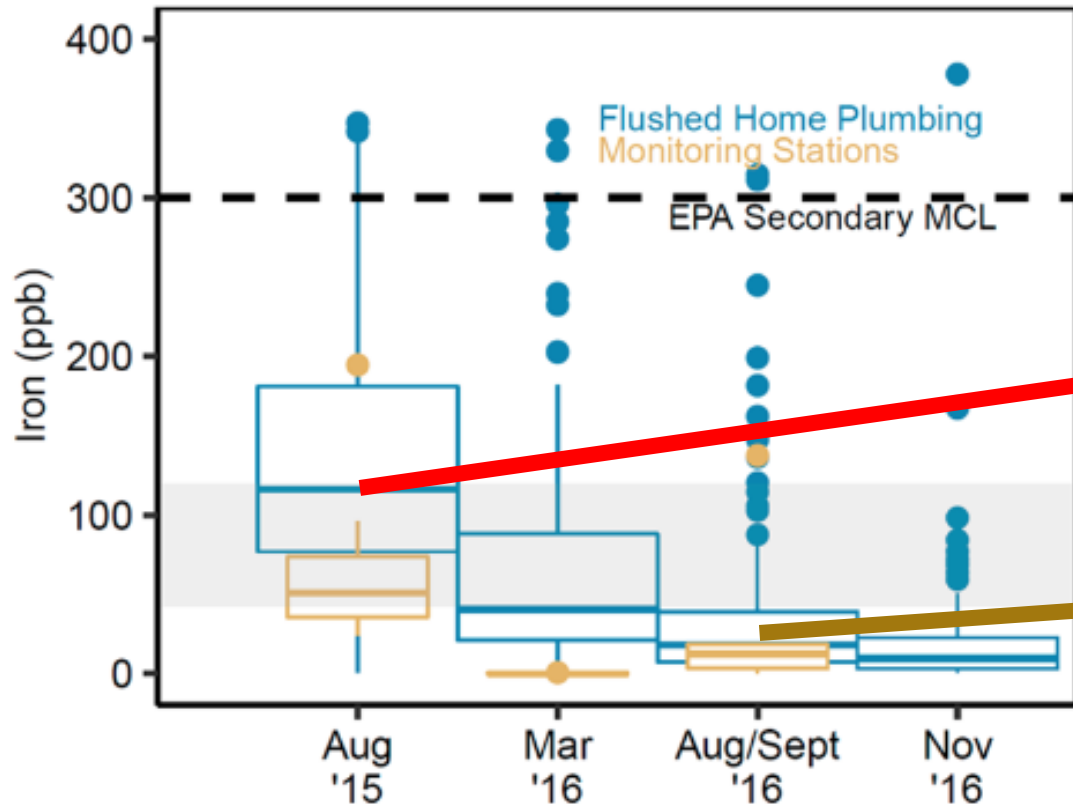
<https://doi.org/10.5942/jawwa.2016.108.0016>

5/29/2024

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# **RULE OF THUMB: IRON ACTS AS A KEY NUTRIENT**

# Iron is a critical nutrient for *Legionella*



Distribution System Operational Deficiencies Coincide with Reported Legionnaires' Disease Clusters in Flint, Michigan. William J. Rhoads, Emily Garner, Pan Ji, Ni Zhu, Jeffrey Parks, David Otto Schwake, Amy Pruden, and Marc A. Edwards  
 Environmental Science & Technology 2017 51 (20), 11986-11995  
 DOI: 10.1021/acs.est.7b01589

Assessment of the Legionnaires' disease outbreak in Flint, Michigan. Sammy Zahran, Shawn P. McElmurry, Paul E. Kilgore, David Mushinski, Jack Press, Nancy G. Love, Richard C. Sadler, and Michele S. Swanson. 2017

# The form of iron matters GREATLY

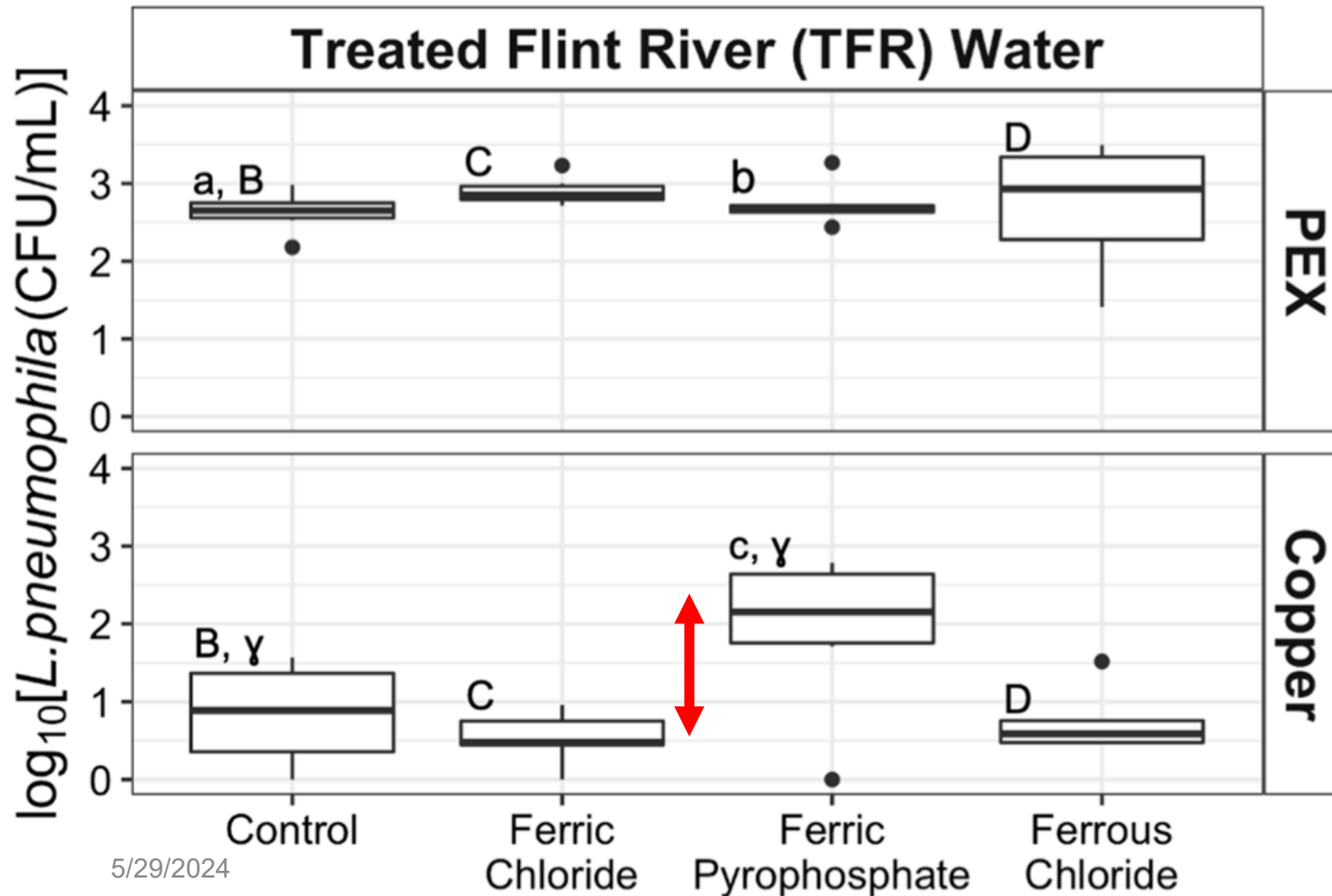
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- **Mild steel, cast iron:** Corrosion, iron release
- **Stainless steel:** Hygienic, medical applications
- **Galvanized iron\*:** Corrosion with heat + bicarbonates/nitrates



\*Galvanic Corrosion of Zinc and Its Alloys. X. G. Zhang 1996 J. Electrochem. Soc. 5/29/2024

# The form of iron matters GREATLY



Water amended with different forms of iron

Modified from: Copper Pipe, Lack of Corrosion Control, and Very Low pH May Have Influenced the Trajectory of the Flint Legionnaires' Disease Outbreak

Rebekah L. Martin, Owen Strom, Yang Song, Didier Mena-Aguilar, William J. Rhoads, Amy Pruden, and Marc A. Edwards

ACS ES&T Water 2022 2 (8), 1440-1450

DOI: 10.1021/acsestwater.2c00182

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**RULE OF THUMB: COPPER PIPING IS AN  
ANTIMICROBIAL**



# A quick note

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- Lots of compelling evidence that copper surfaces sustain less microbial and pathogen growth



Flint causes  
bleeding on touch

**It depends on the form!!**



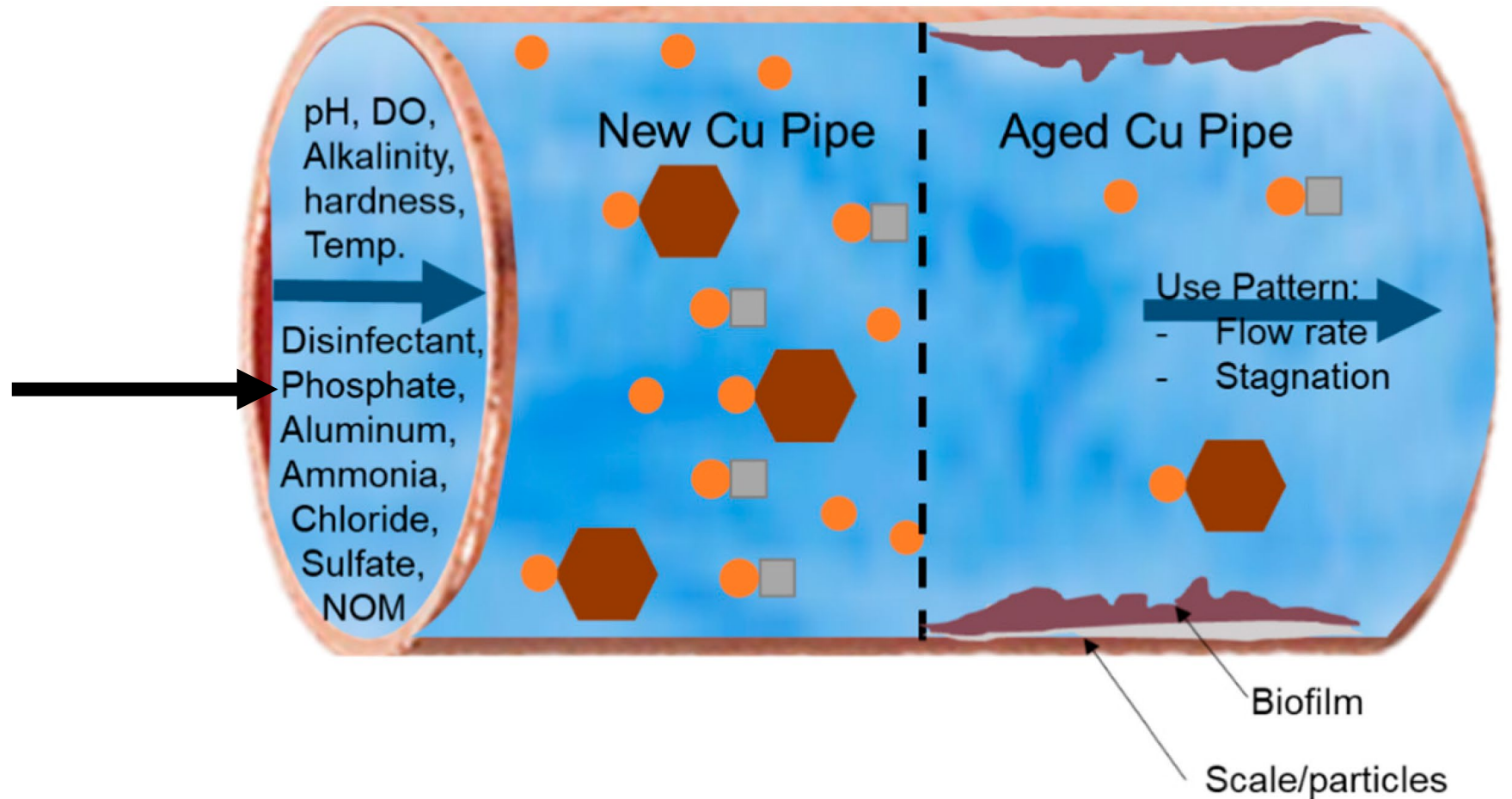
Or does it?

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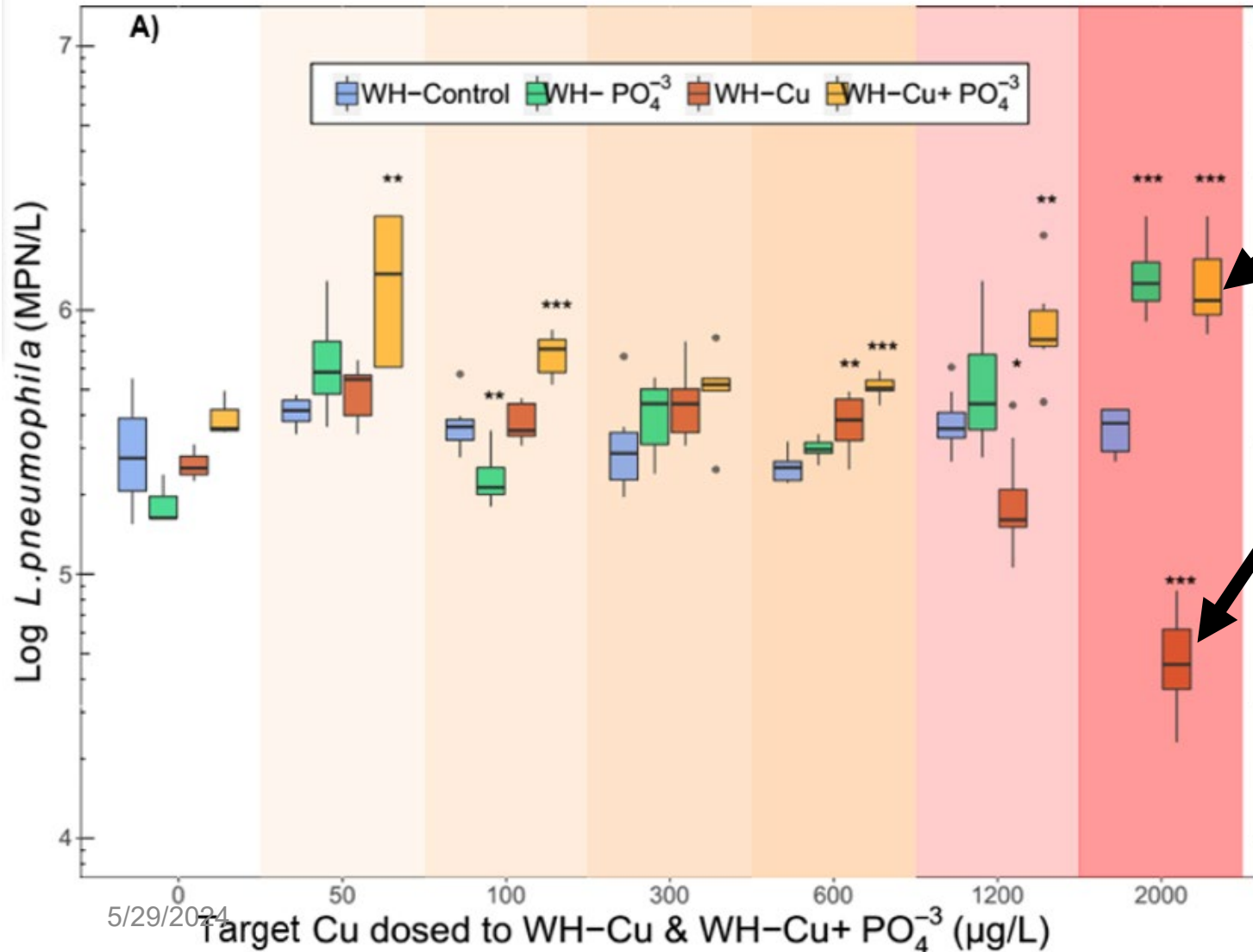
Abraham C. Cullom<sup>1</sup>, Rebekah L. Martin<sup>1,2</sup>, Yang Song<sup>1</sup>, Krista Williams<sup>3</sup>, Amanda Williams<sup>4</sup>, Amy Pruden<sup>1</sup> and Marc A. Edwards<sup>1,\*</sup>



## Common corrosion control



# Copper with/without phosphate in water heaters



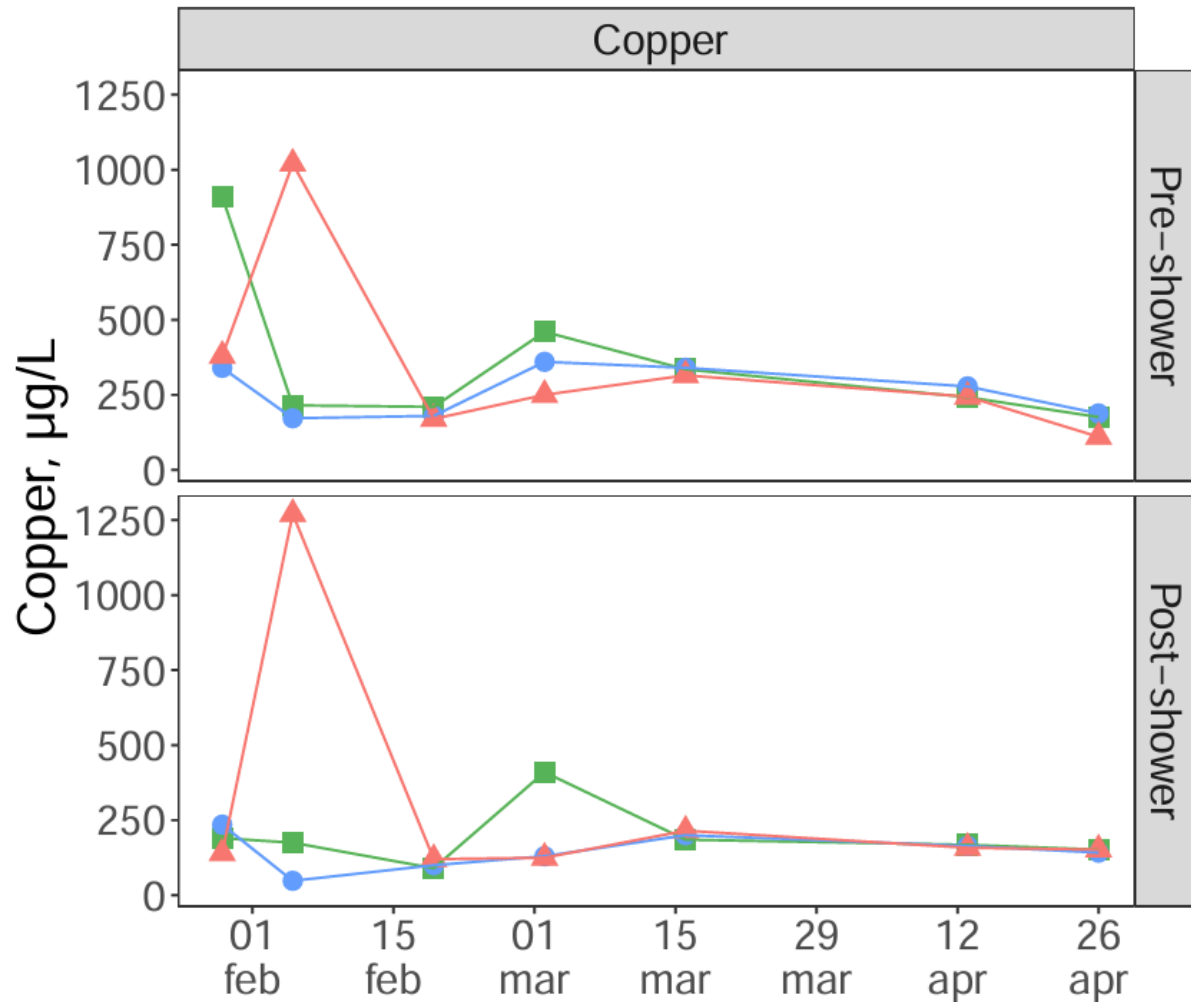
Cu + Phosphate

Cu alone

**Phosphate stops biocidal activity**

Yang Song, Amy Pruden, William J Rhoads, Marc A Edwards. Pilot-scale assessment reveals effects of anode type and orthophosphate in governing antimicrobial capacity of copper for *Legionella pneumophila* control. *Water Research*.2023.

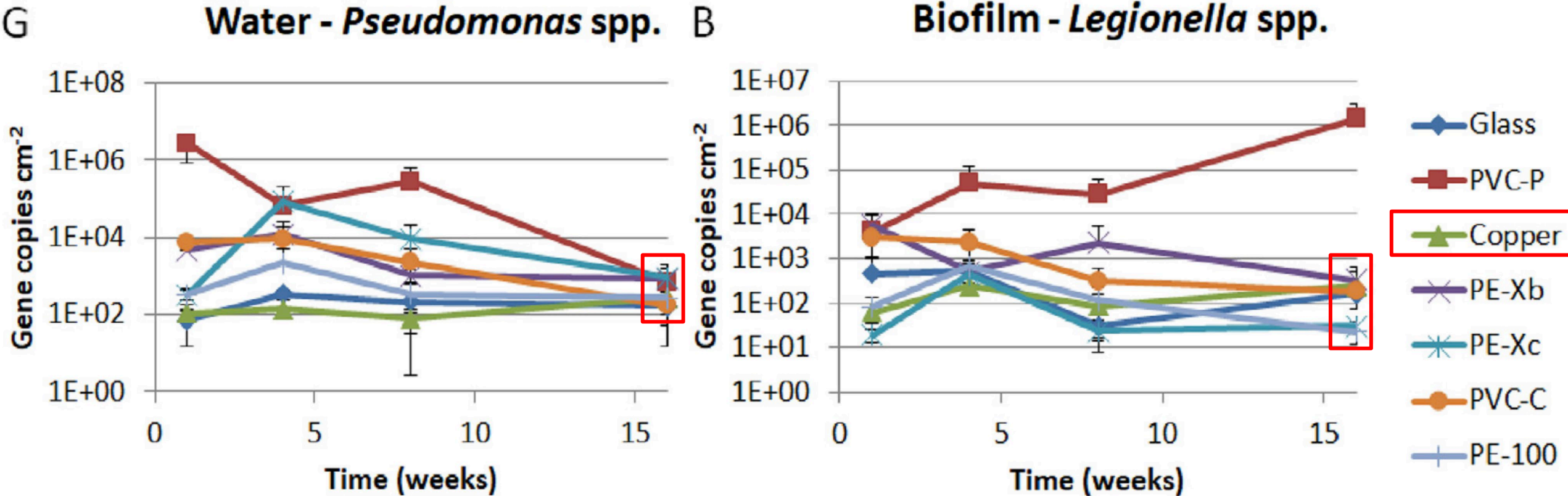
# Copper leaching diminishes with time



- Passivation
- Development of scale
- Biofilm development
  
- Rate affected by usage, chemistry, etc.



# Copper's 'edge' diminishes with time



K.L.G. Learbuch, H. Smidt, P.W.J.J. van der Wielen.

Influence of pipe materials on the microbial community in unchlorinated drinking water and biofilm. *Water Research*, Volume 194, 2021, 116922, ISSN 0043-1354, <https://doi.org/10.1016/j.watres.2021.116922>.



# Is copper good?

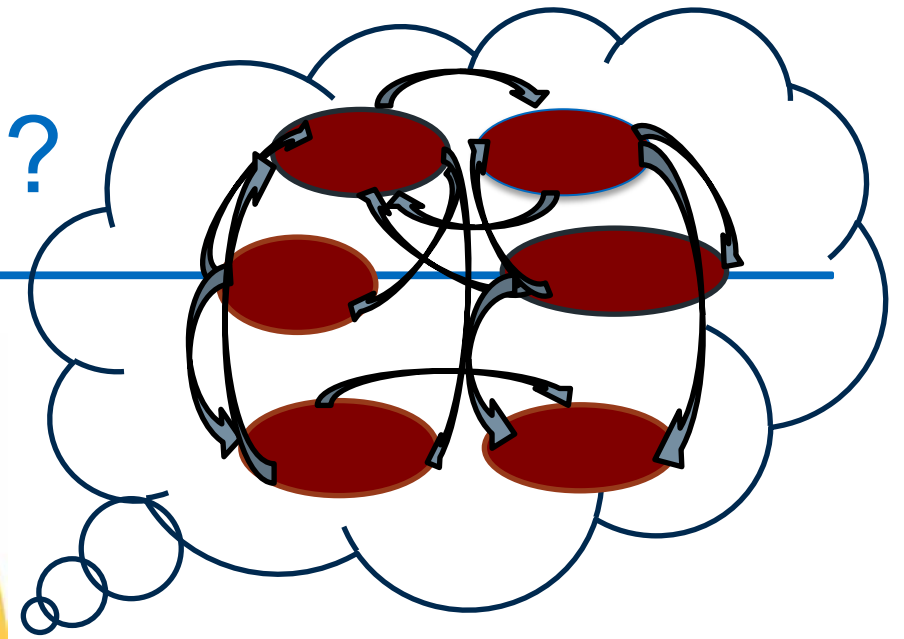
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## The Unlearned Common Person

Is copper good?

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**It depends!!**

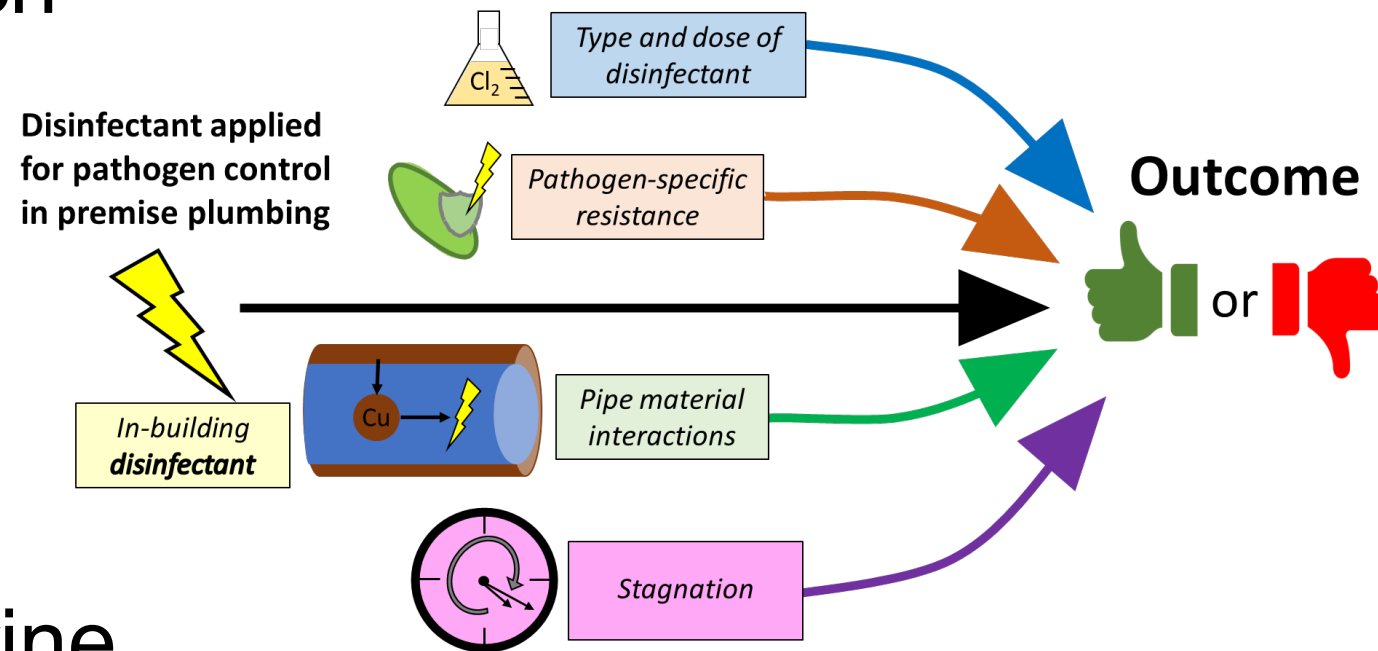
**The Educated Expert**

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# IMPORTANT INTERACTIONS

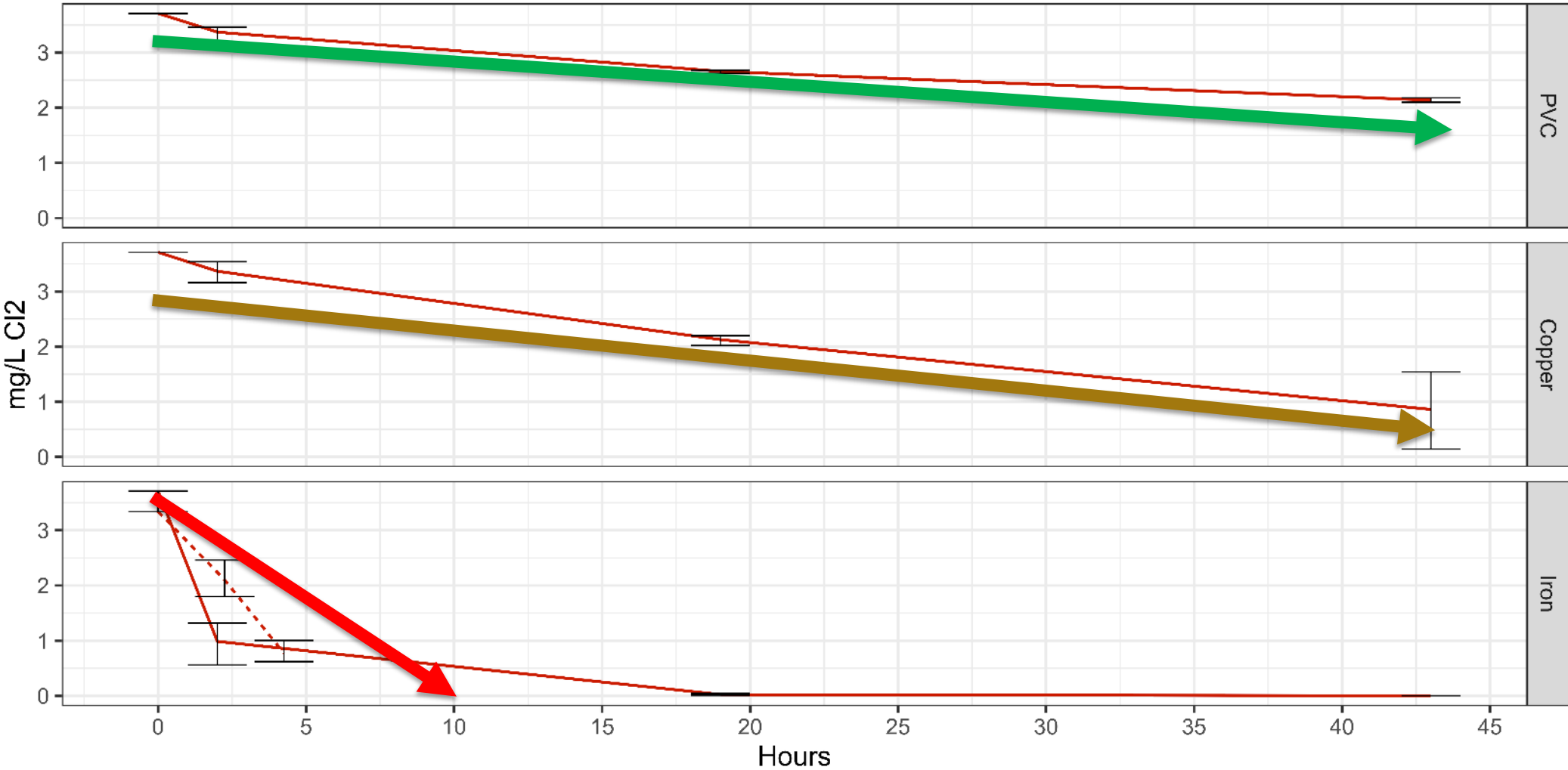
# Disinfectant Demand

- Need disinfectants to reach pathogens!
- Plastics least reactive
- Iron, corroded steel most reactive
  - Growth of nitrifiers → Chloramine Decay
- Copper: Catalysis of chlorine and chloramine decay

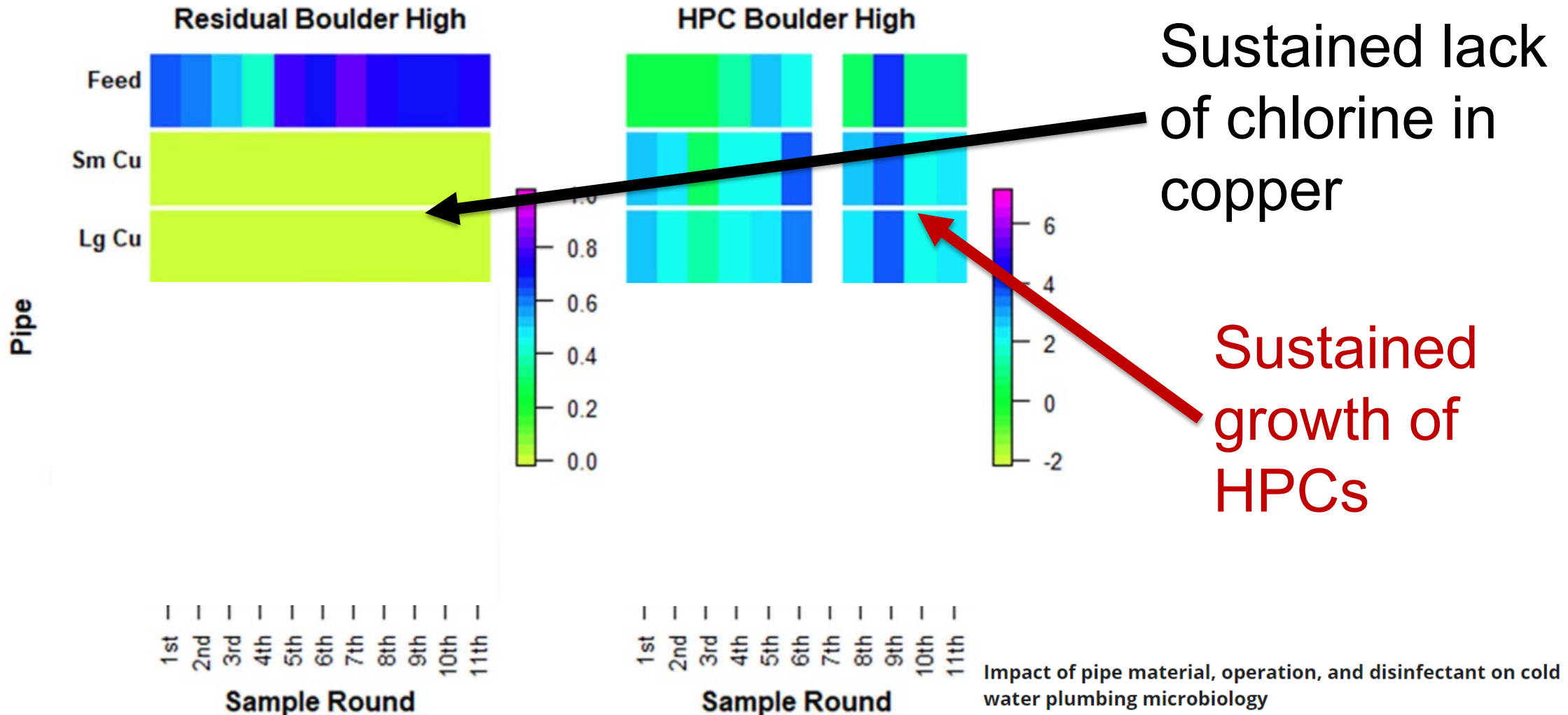


Abraham Cullom, Mattheu Storme Spencer, Myra D. Williams, Joseph O. Falkinham, Amy Pruden, Marc A. Edwards. Influence of pipe materials on in-building disinfection of *P. aeruginosa* and *A. baumannii* in simulated hot water plumbing. *Water Research X*. Volume 21. 2023,

# Disinfectant Demand

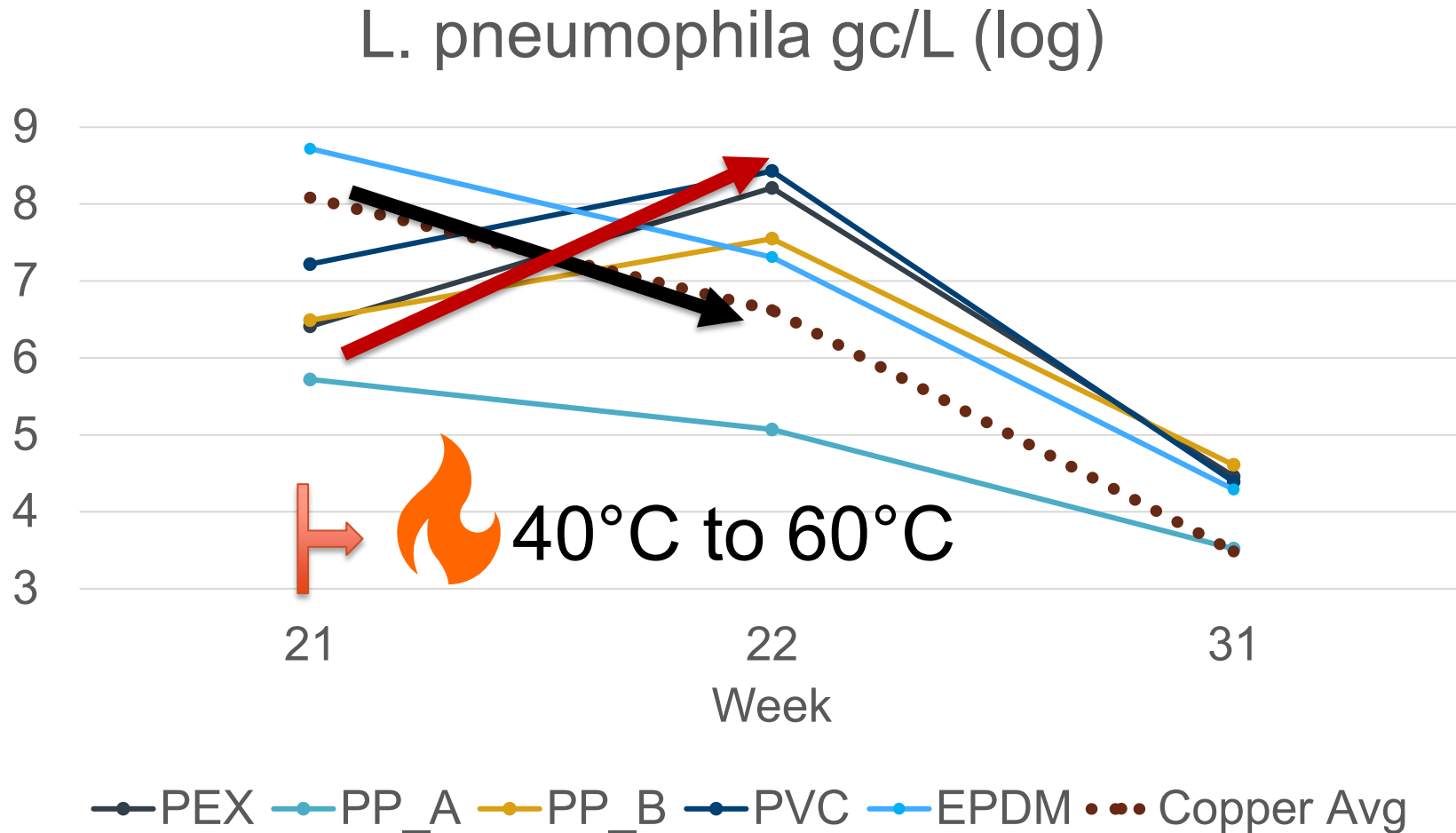


# Disinfectant Demand





# Heat affects copper and carbon release

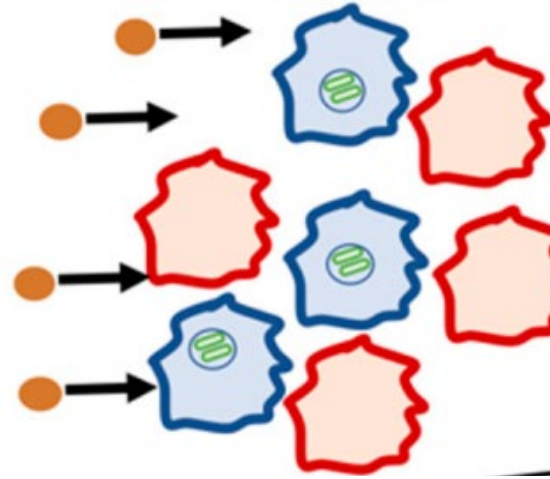


Decrease in copper

Increase in most plastics

# Copper-Amoeba Interactions

- Amoebae critical to *Legionella* lifecycle
- Copper may favor *Legionella* host amoebae
- More hosts = more *Legionella*



Lu, J.; Buse, H.Y.; Gomez-Alvarez, V.; Struewing, I.; Santo Domingo, J.; Ashbolt, N.J. Impact of drinking water conditions and copper materials on downstream biofilm microbial communities and *Legionella pneumophila* colonization. *J. Appl. Microbiol.* **2014**, *117*, 905–918.

Buse, H.Y.; Lu, J.; Lu, X.; Mou, X.; Ashbolt, N.J. Microbial diversities (16S and 18S rRNA gene pyrosequencing) and environmental pathogens within drinking water biofilms grown on the common premise plumbing materials unplasticized polyvinylchloride and copper. *FEMS Microbiol. Ecol.* **2014**, *88*, 280–295.

Review

**Critical Review: Propensity of Premise Plumbing Pipe Materials to Enhance or Diminish Growth of *Legionella* and Other Opportunistic Pathogens**

Abraham C. Cullom<sup>1</sup>, Rebekah L. Martin<sup>1,2</sup>, Yang Song<sup>1</sup>, Krista Williams<sup>3</sup>, Amanda Williams<sup>4</sup>, Amy Pruden<sup>1</sup> and Marc A. Edwards<sup>1,\*</sup>

# Antibiotic resistance

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**Antibiotic  
resistance  
gene (ARG)**



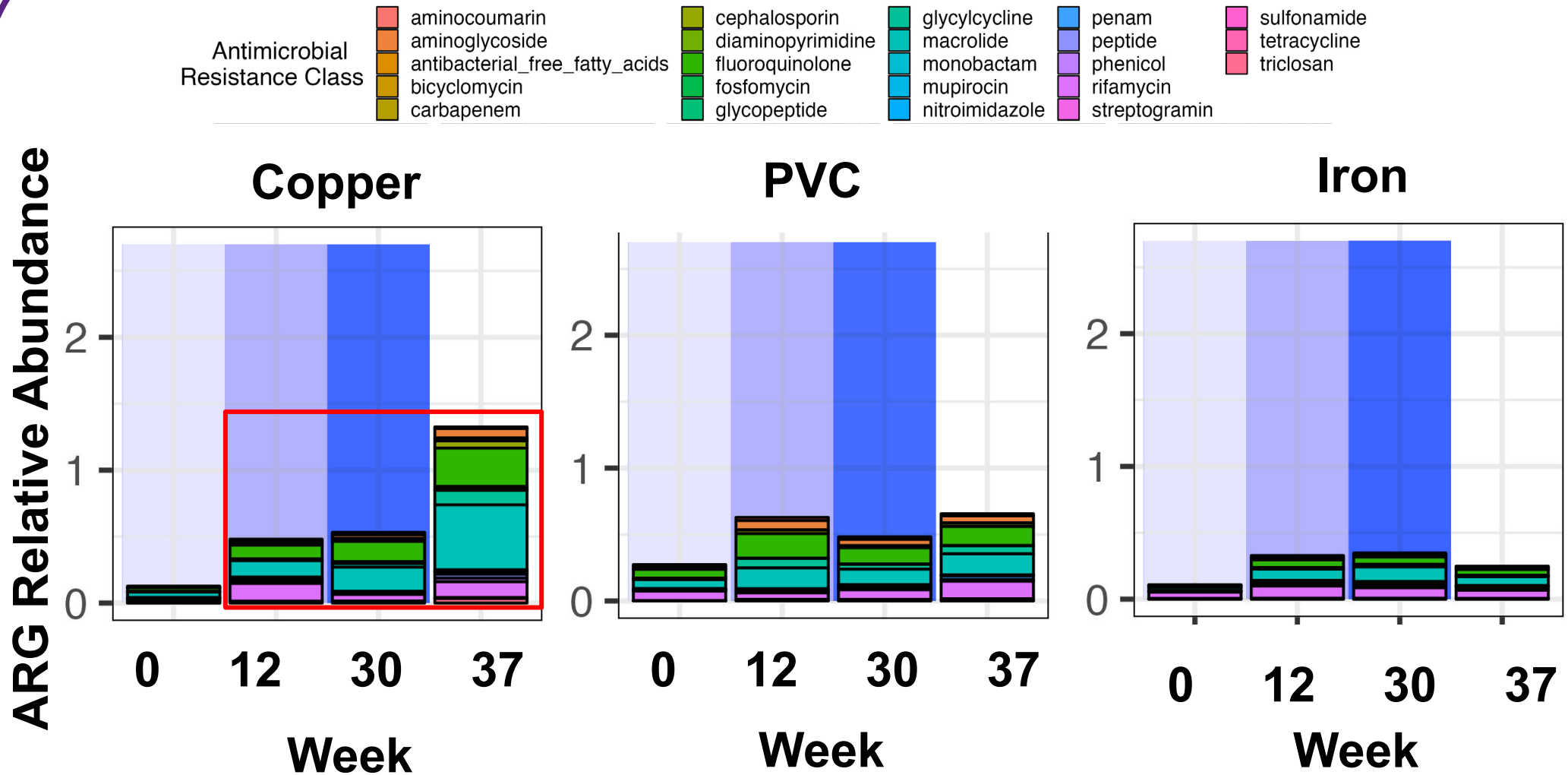
**Antibiotic  
resistance**

**Metal resistance  
gene**



**Antibiotic  
resistance**

# Antibiotic Resistance Genes



Premise plumbing pipe materials and in-building disinfectants shape potential for proliferation of pathogens and antibiotic resistance genes

Authors: Abraham Cullom, Matheu Storme Spencer, Myra D. Williams, Joseph Oliver Falkinham III, Connor Brown, Marc A. Edwards, Amy Pruden

# Key Takeaways

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- 1. Rules of thumb are subject to change dramatically with time and water quality.**
- 2. Pipes within one 'type' vary substantially**
- 3. Effects on health risk mediated by large web of factors**



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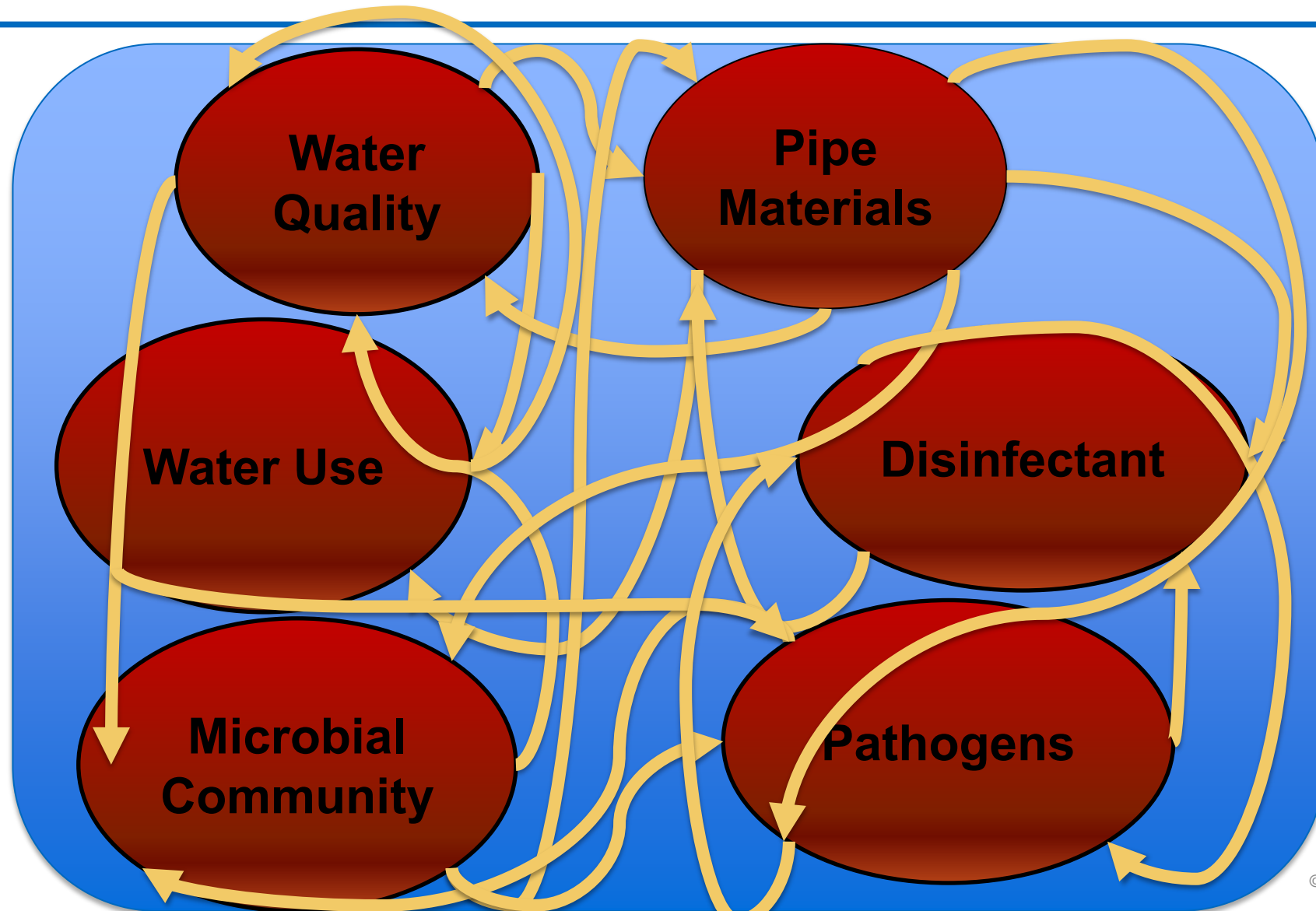
**THANK YOU**  
Questions?

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# Understanding In-Building Plumbing



# Is copper good?

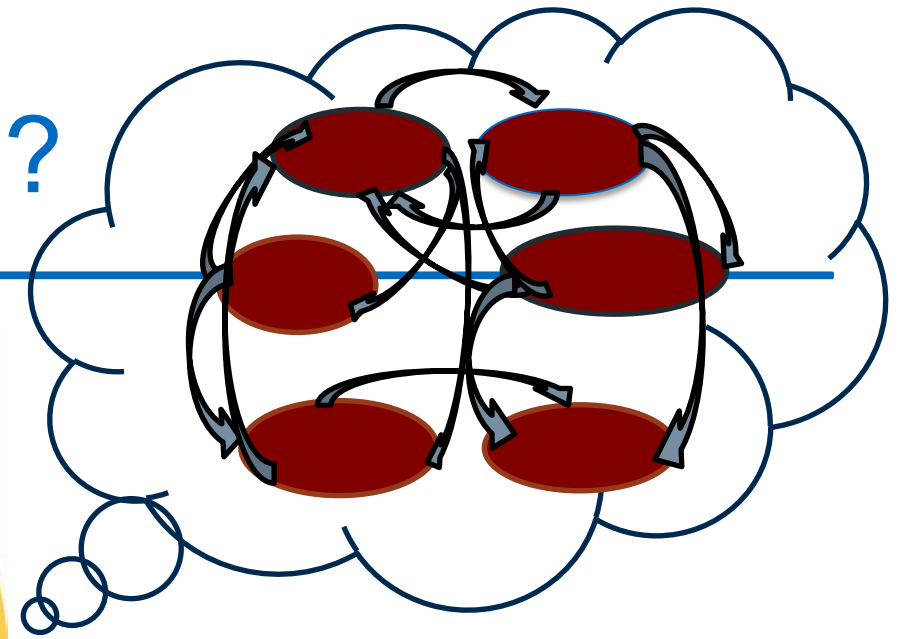
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## The Unlearned Common Person

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**It depends!!**

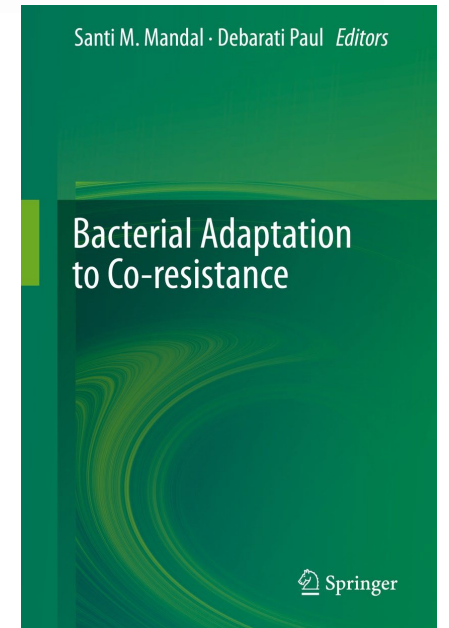
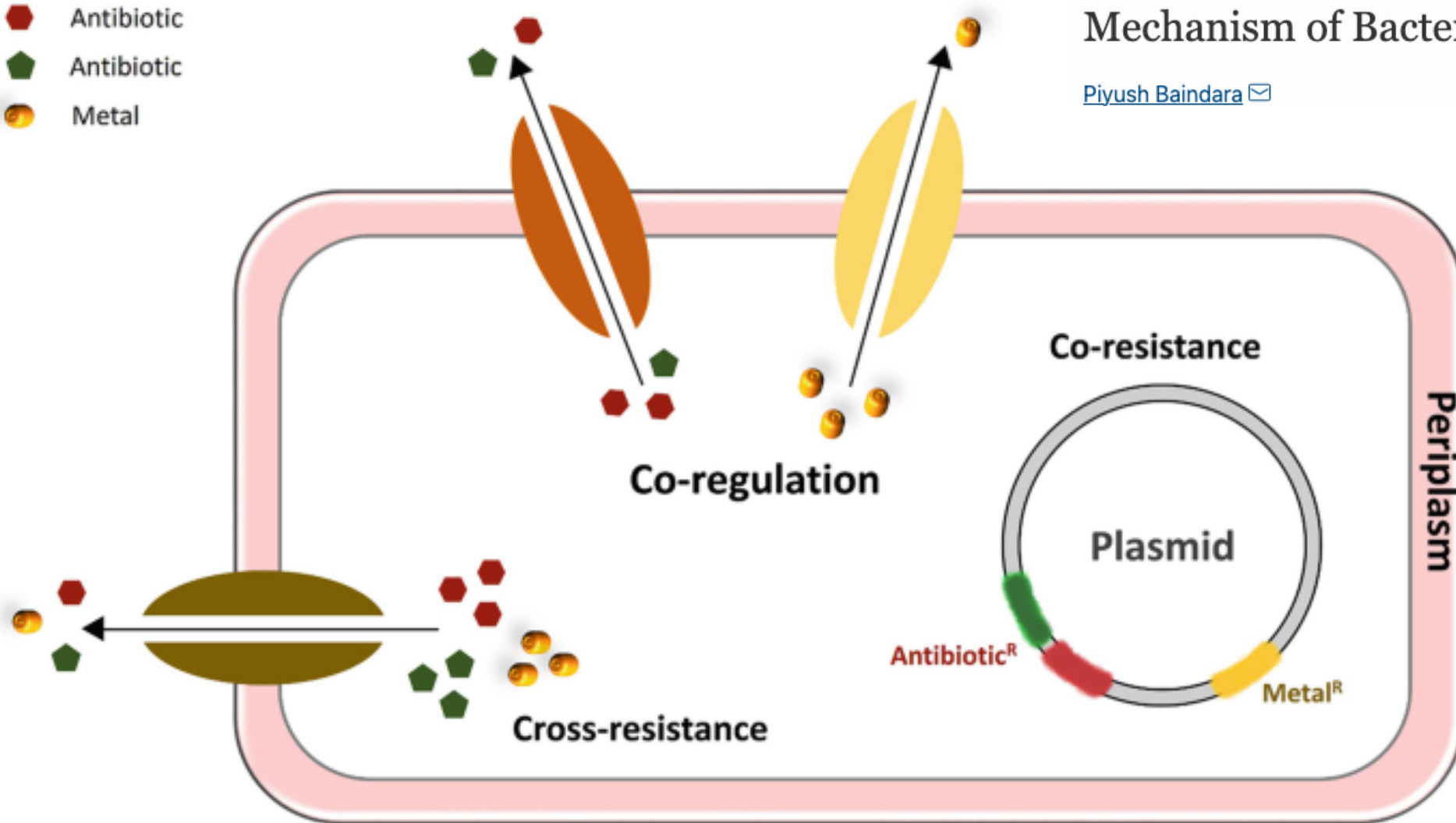
**The Educated Expert**

# Antibiotic resistance

- Antibiotic
- Antibiotic
- Metal

## Mechanism of Bacterial Co-resistance

[Piyush Baidara](#) ✉





# Plastic: Practicalities

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- **PEX, PVC, CPVC, PE, HDPE, PP**
- Inexpensive
- Light-weight
- Flexible (PEX)
- Brittleness (water and temp conditions)
- Fun colors



# Copper: Practicalities



- Thickness:  $M < L < K$ 
  - Cost and durability
- M: Cold water lines
- L: Hot & Cold Water lines
- Pricey
- Durable



## Steel/Iron: Practicalities



### Stainless

- Strength
- Longevity
- Cost \$\$\$
  - Weight
- Installation

### Mild/ Galvanized

- Strength
- Longevity
  - Cost
- Weight



# Copper in Dutch Water

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Attempting to grow  
*Acinetobacter*

TWICE the copper  
coming off the pipes

- Lower organics
- Less aggressive  
corrosion control



# Copper is an important micronutrient

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MORE growth of pathogens with copper:

- Bench-scale coupon studies:
  - More *Legionella* compared to PVC
  - More *Mycobacterium abscessus* compared to uPVC
- Field Study: Copper pipe systems more frequently colonized than plastic or galvanized iron

S.N. Mullis, J.O. Falkinham, Adherence and biofilm formation of *Mycobacterium avium*, *Mycobacterium intracellulare* and *Mycobacterium abscessus* to household plumbing materials, *Journal of Applied Microbiology*, Volume 115, Issue 3, 1 September 2013, Pages 908–914, <https://doi.org/10.1111/jam.12272>

Helen Y. Buse, Jingrang Lu, Ian T. Struewing, Nicholas J. Ashbolt,

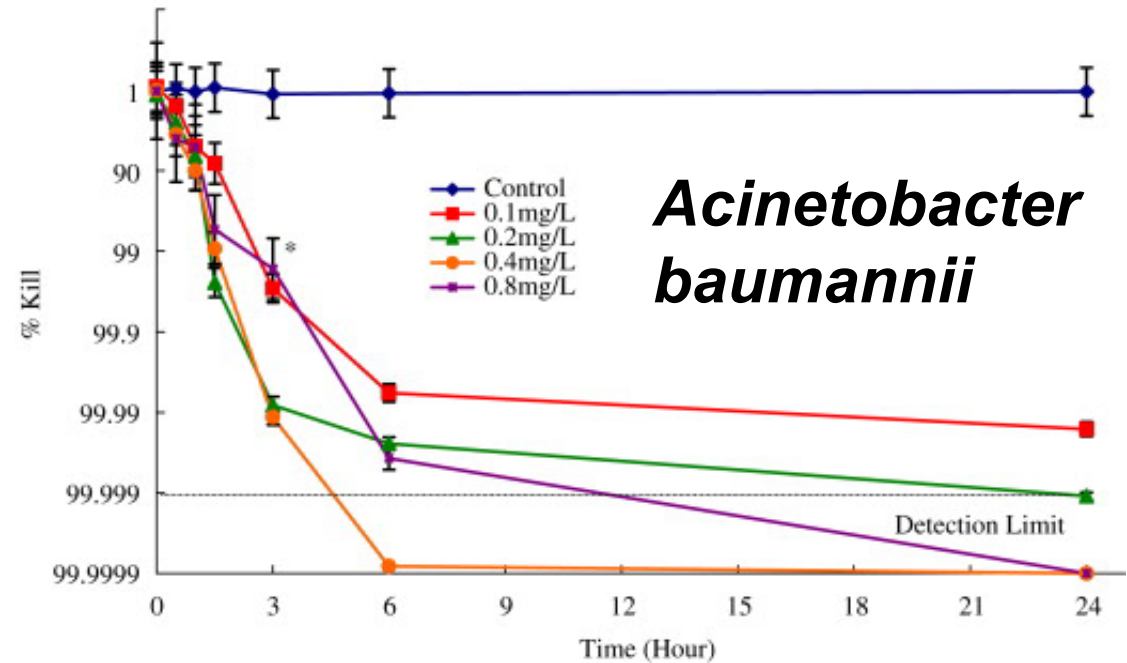
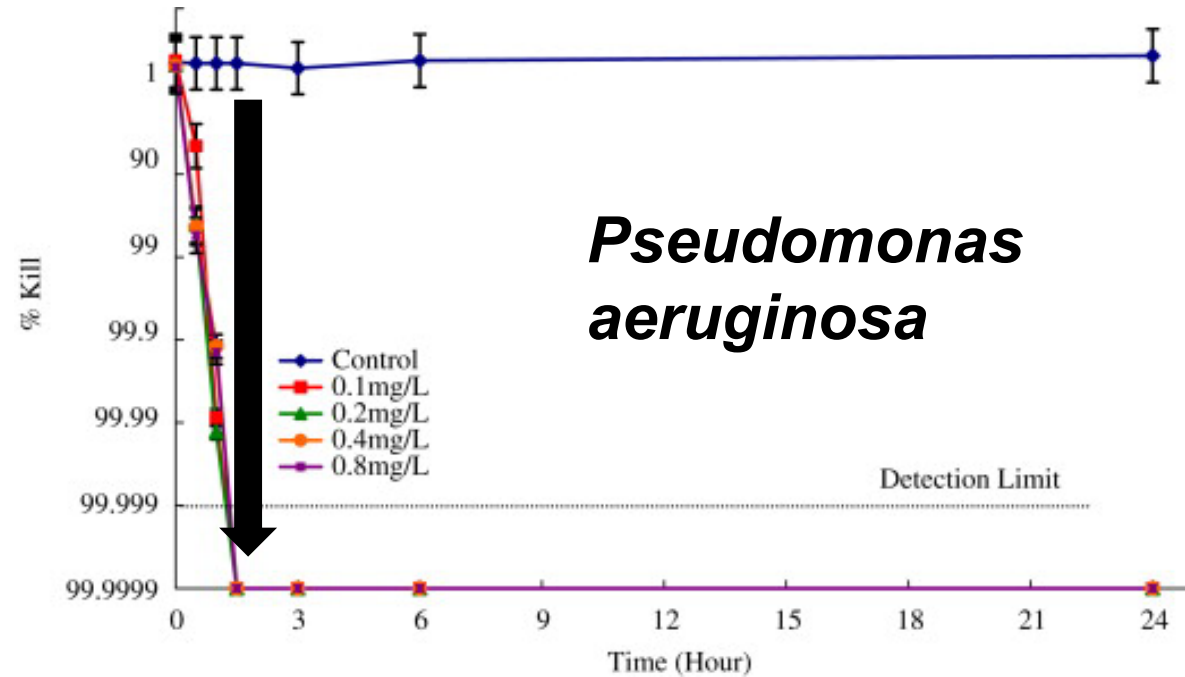
Preferential colonization and release of *Legionella pneumophila* from mature drinking water biofilms grown on copper versus unplasticized polyvinylchloride coupons. *International Journal of Hygiene and Environmental Health*. 2014

Werner Mathys, Juliane Stanke, Margarita Harmuth, Elisabeth Junge-Mathys. Occurrence of *Legionella* in hot water systems of single-family residences in suburbs of two German cities with special reference to solar and district heating. *International Journal of Hygiene and Environmental Health*. 2008

# Variance in Copper Resistance: Organism

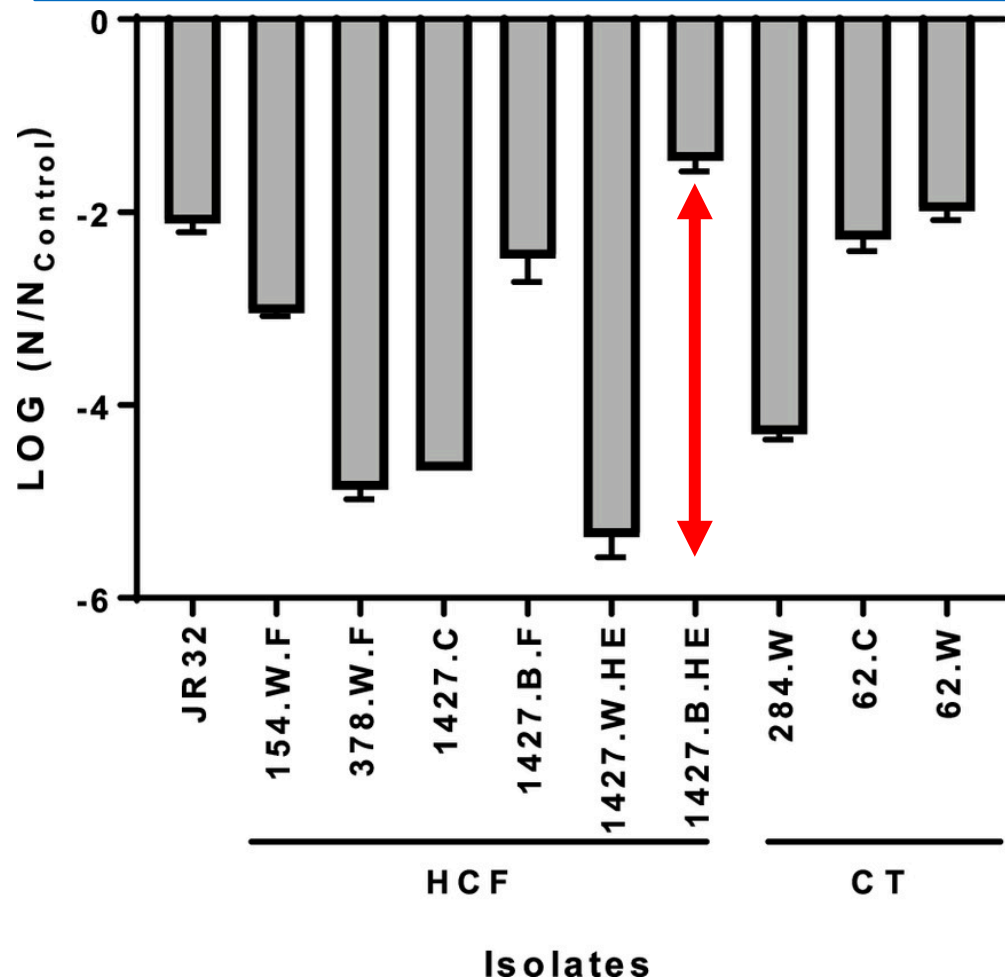
*Pseudomonas aeruginosa*

*Acinetobacter baumannii*



Hsin-I Huang, Hsiu-Yun Shih, Chien-Ming Lee, Thomas C. Yang, Jiunn-Jyi Lay, Yusen E. Lin. In vitro efficacy of copper and silver ions in eradicating *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia* and *Acinetobacter baumannii*: Implications for on-site disinfection for hospital infection control. *Water Research*. 2008

# Variance in Copper Resistance: Strain-to-strain!



- *Legionella pneumophila* from one hospital
- ~10,000X difference in susceptibility
- Same serogroup, same water system!