POLYTECHNIQUE MONTRÉAL

NSERC INDUSTRIAL CHAIR ON DRINKING WATER

Detecting the unintended consequences of energy and water conservation on water quality at the tap

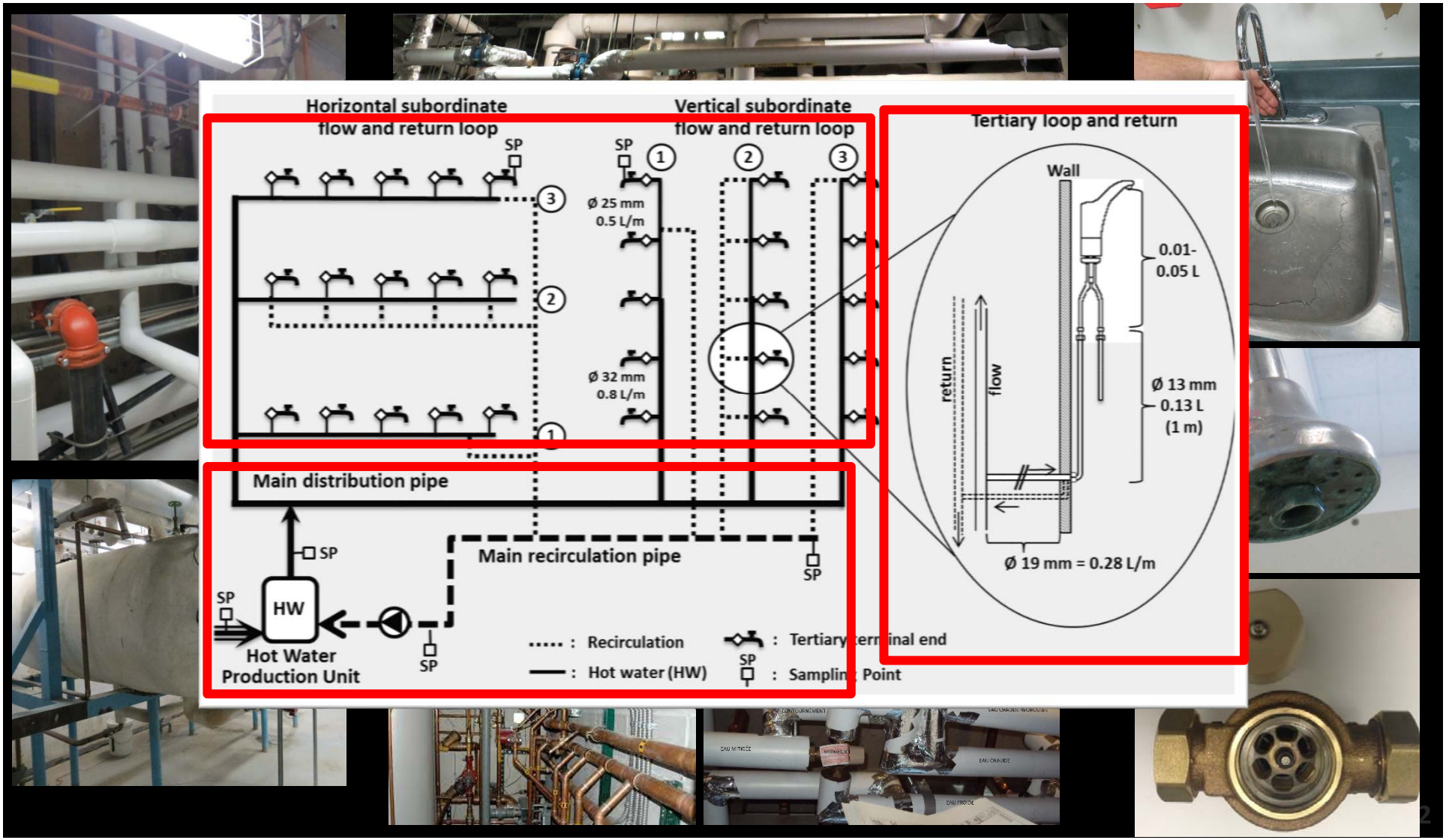
Michèle Prévost

Principal Chairholder,

NSERC Industrial Chair on Drinking Water

NEMC Conference, DC Aug 10 2017

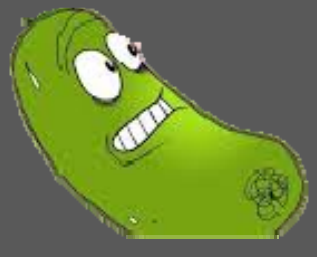
Premise plumbing DS are complex



WQ in premise plumbing

Microbial

- Indicators and pathogens
- Regrowth, intrusion and backflow



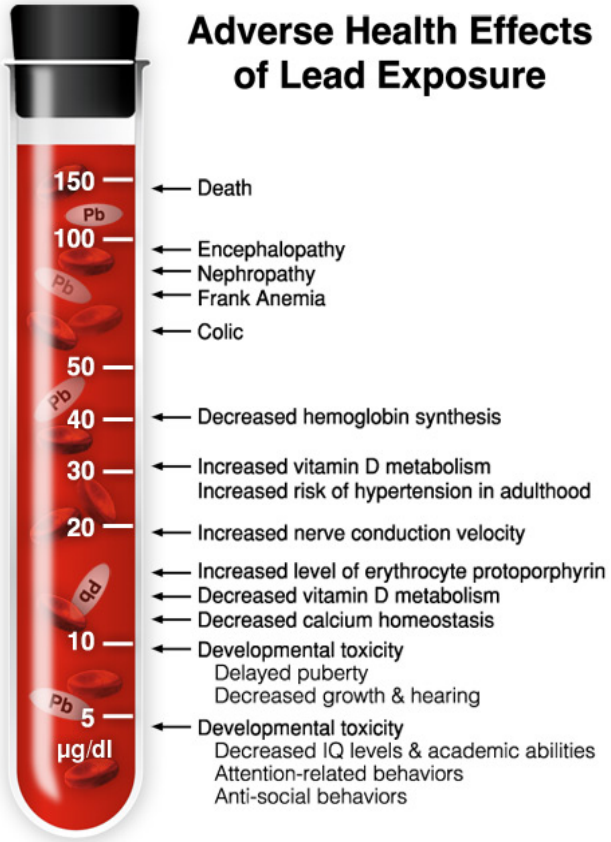
Chemical

- Metals (Pb, Cu, Sn, etc.)
- Backflow chemicals

1. **Location of contamination**
   - Main pipes? dead-ends?
   - Premise plumbing? Reservoirs? Taps?
   - Bad areas or materials?
2. **Water quality goals**
   - Biostability goals?
   - Health based WQ standards?
   - Protection of susceptible populations?

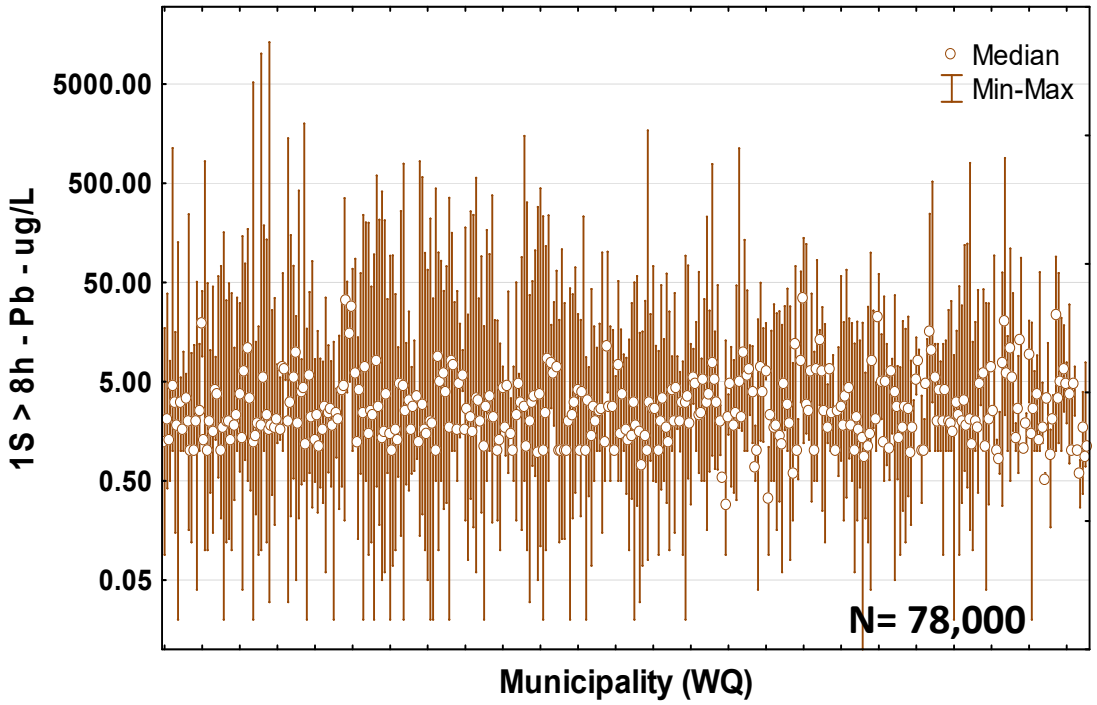
Pb: Tap water contribution to children BLLs

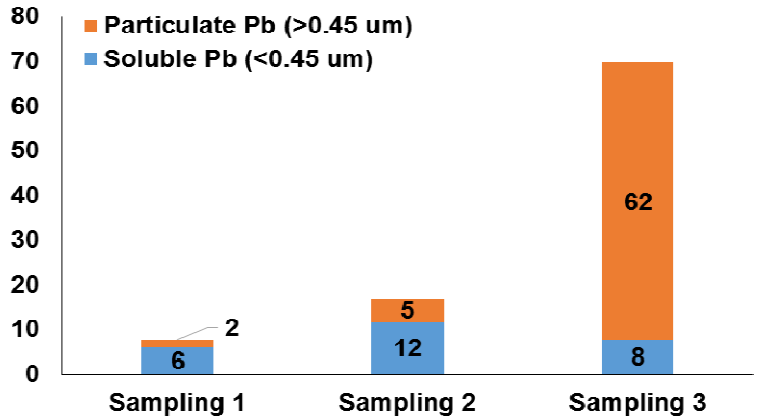
- Tap water is one of the remaining sources of exposure
- No threshold without health effects
- 2011: WHO retracts the 25 µg/kg p.c./d. to calculate 10 µg/dL (BLL)
  - Basis for the 10 µg/L standard in DW
- Health Canada new proposal: maximum 5 µgPb/L in tap water

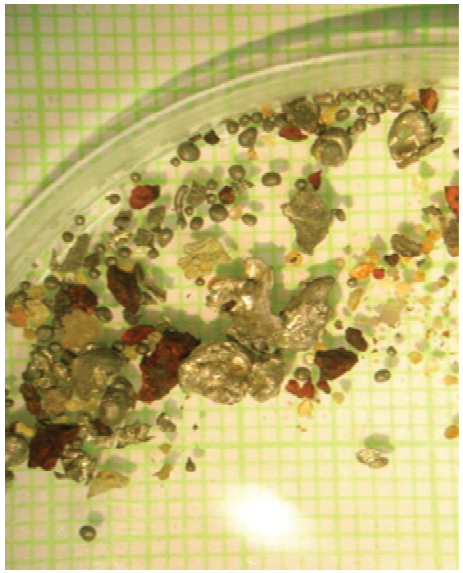


Sources images:
http://www.ehatlas.ca/lead/human-impact/health-concerns
http://www.webmd.com/parenting/baby/baby-bottles
http://www.wealthandfinance-intl.com/

Pb concentrations at the tap in large buildings





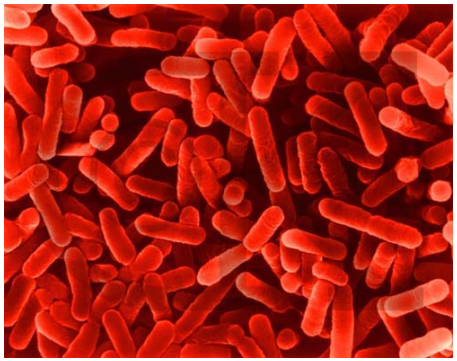


Deshommes et al 2012, 2016

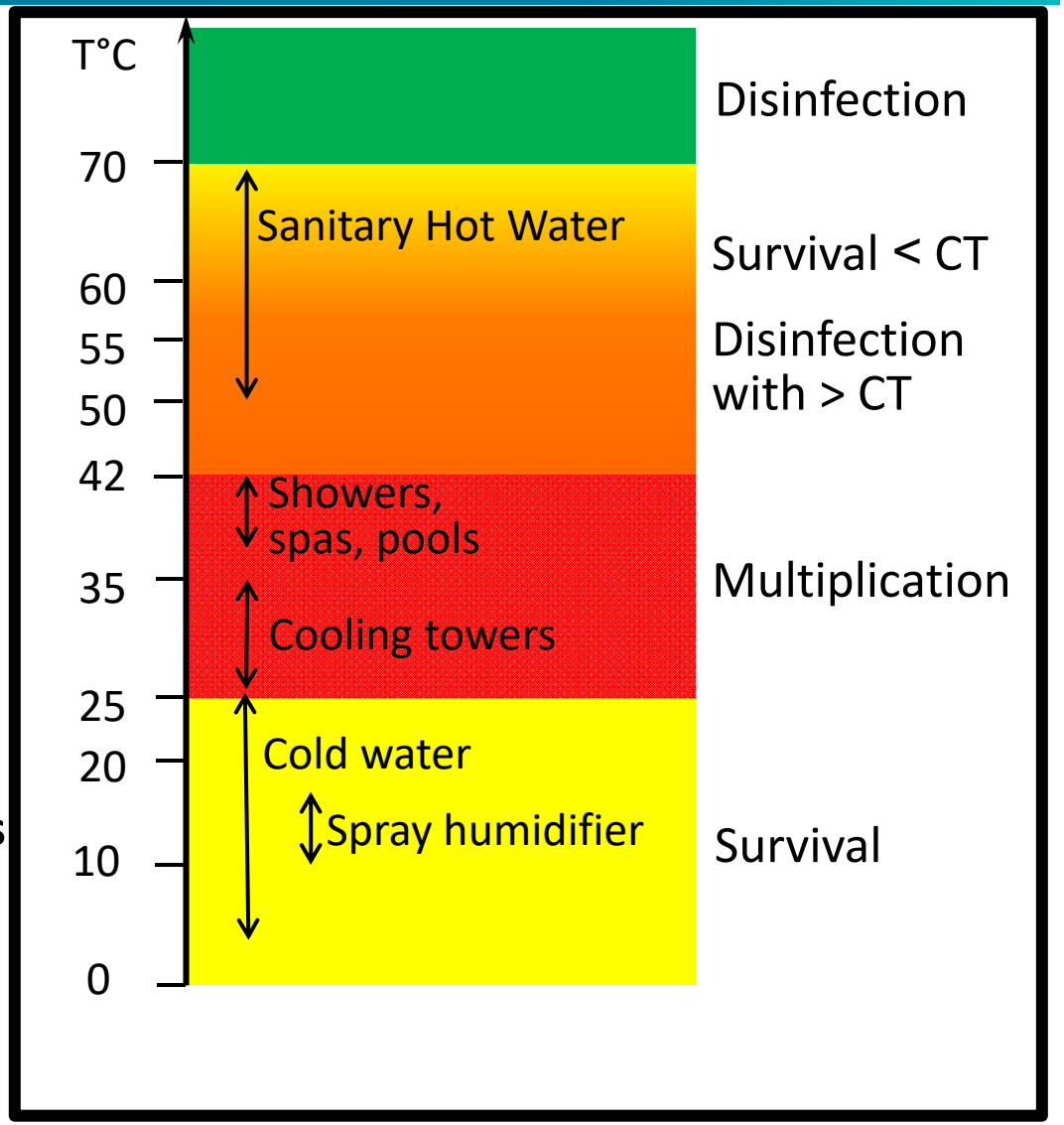
Bacterial amplification in premise plumbing

- **Opportunistic pathogens (OP) associated with water can cause severe infections through direct or indirect contact**
- **Important source of nosocomial infections**
  - **30-50% *P. aeruginosa* infections in intensive care unit**
  - ***L. pneumophila* causes up to 10% of nosocomial pneumonia and is the first cause of waterborne illness in NA**
  - **MAC, *Aspergillus*, etc.**
- **Scarce regulation in drinking water systems**

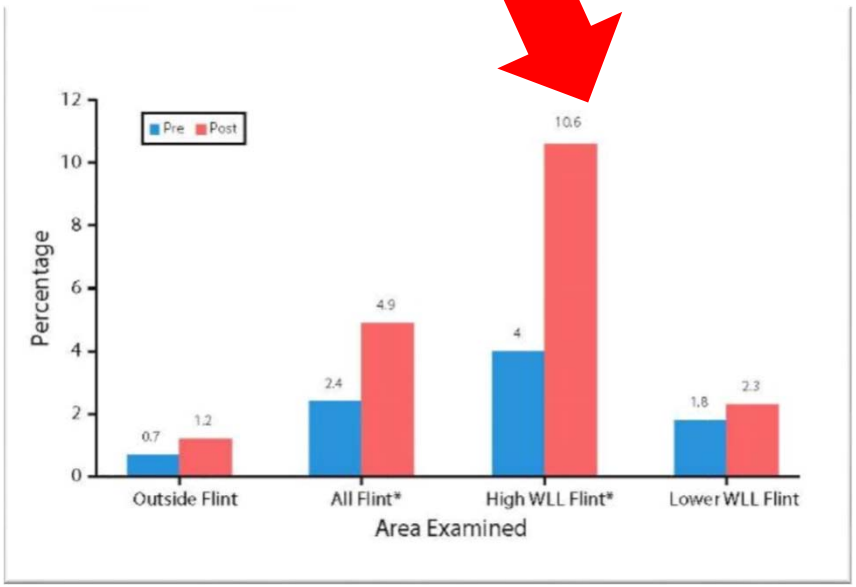
Legionella pneumophila



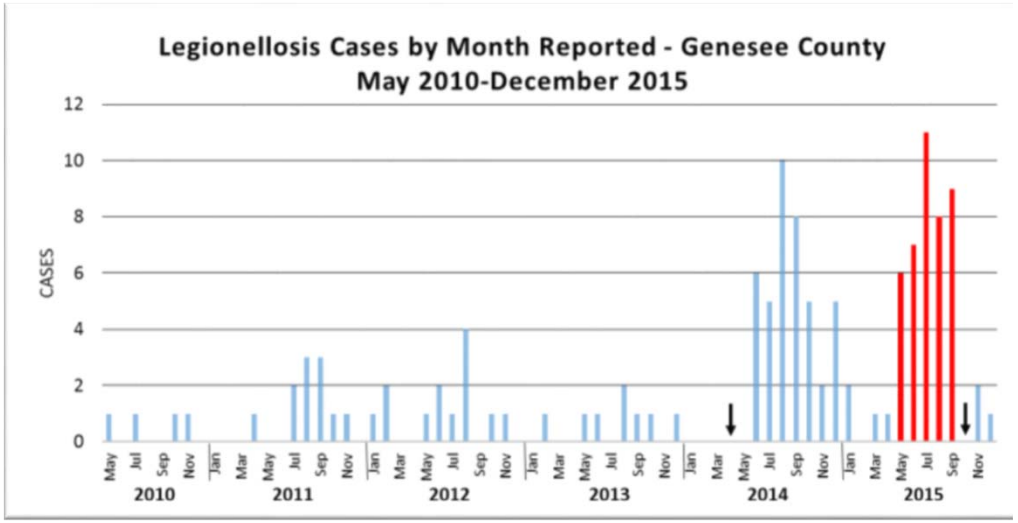
- **10 to 50% positivity reported for faucets and showerheads**
- **Transmission via aerosols generated by point-of-use devices**
- **Optimal growth temperature between 25 and 42°C**



Red water causes elevated BLLs and legionellosis in Flint, Michigan



Hanna Attisha 2016



MDHHS 2015

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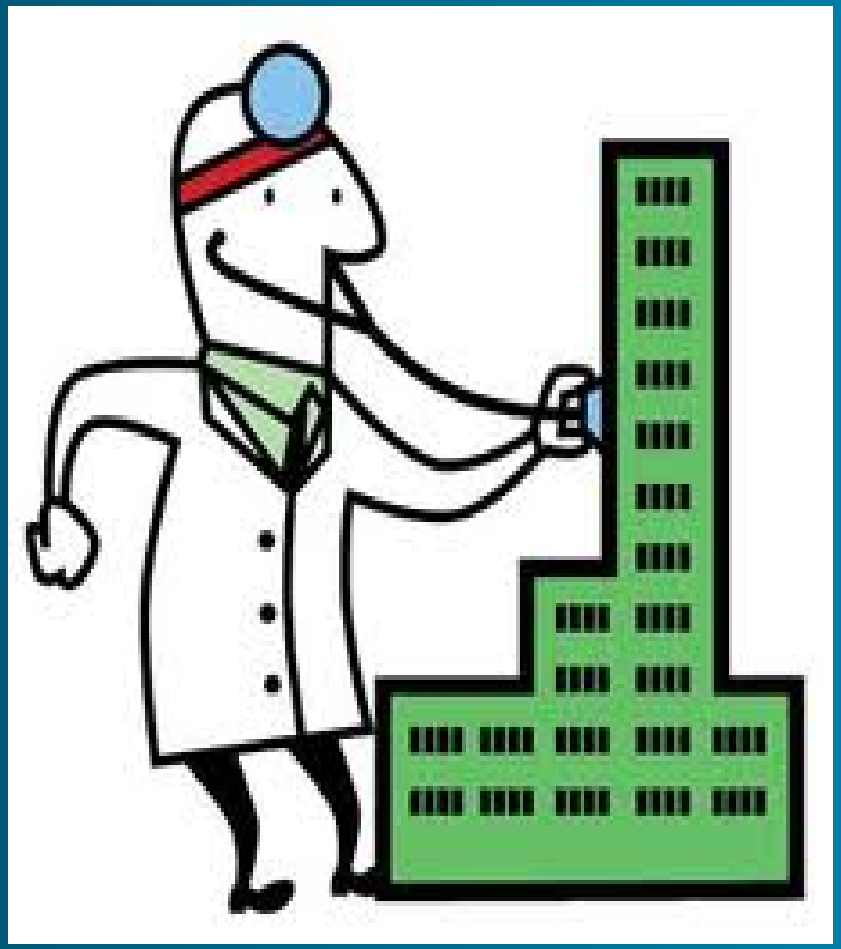


Energy conservation in large buildings

How significant is the health risk in large buildings?

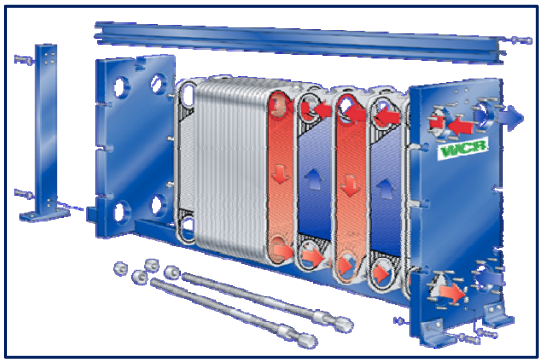
Typical Energy/Water Conservation Approaches

Water conservation

- Flow restriction devices such as aerators
- Low flow devices = low flow to drains

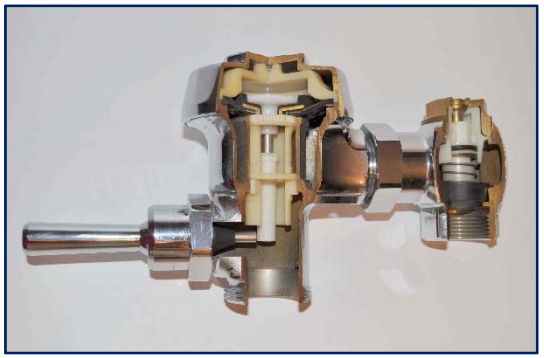
Hot water energy conservation

- Lower reference set temperatures (heated and return loop)
- Multiplication of energy conservation devices (heat exchangers at the system and device levels)



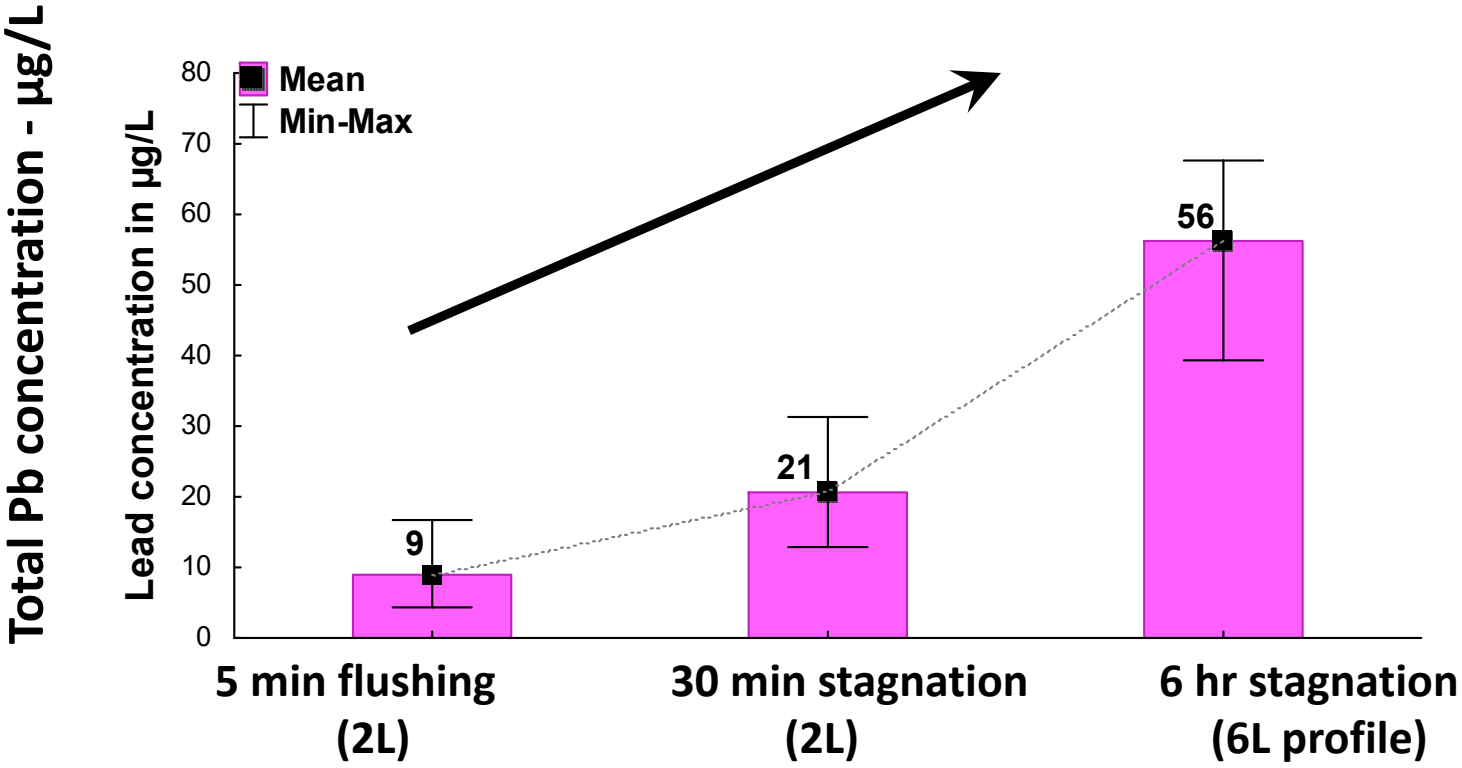
Thermal mixing valves –TMVs

- Burn prevention
- Complex devices adding significant lukewarm stagnation volumes

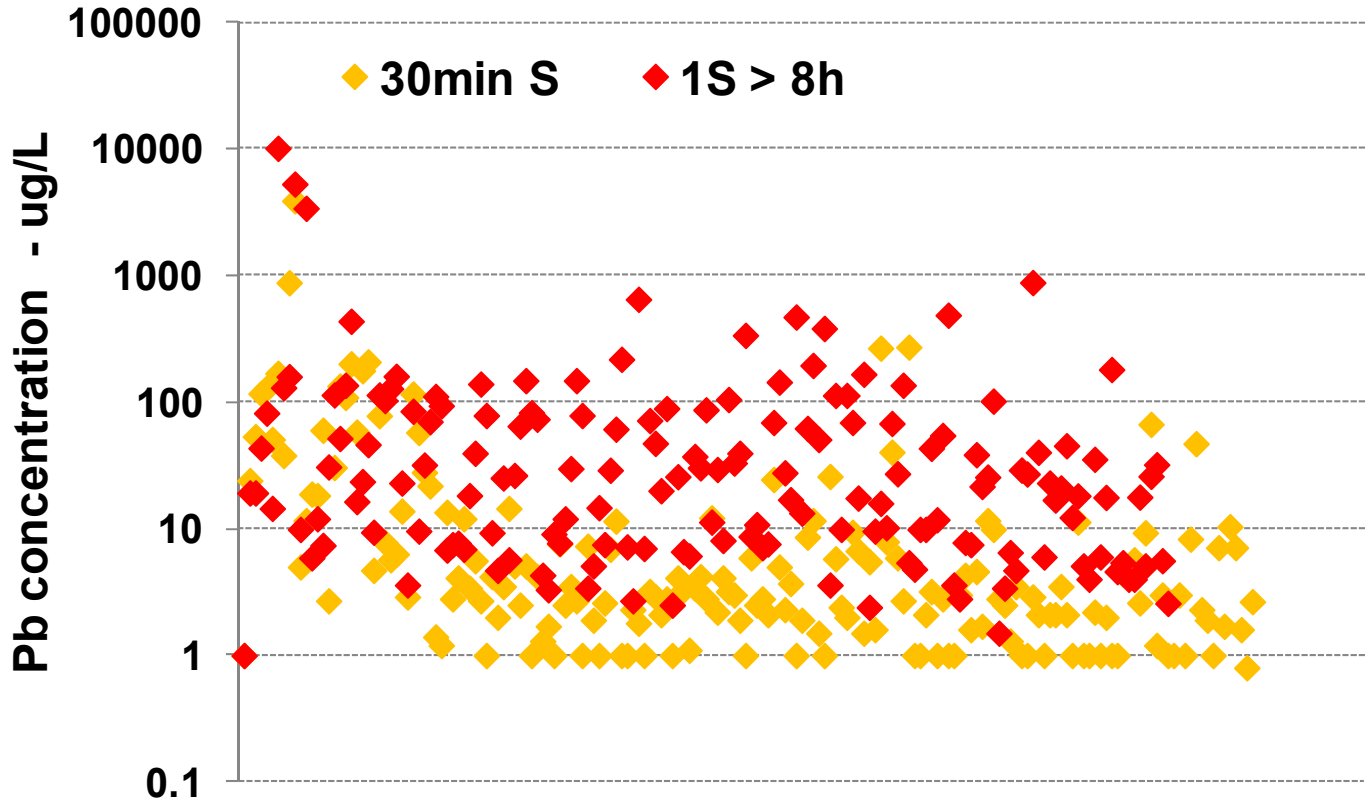


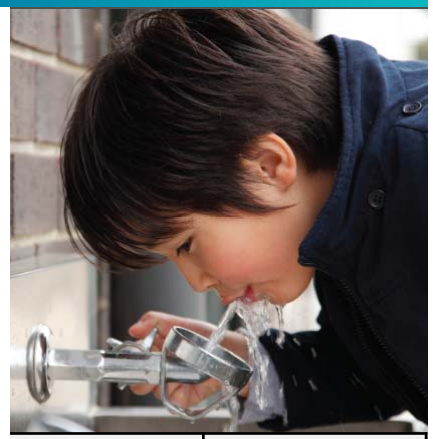
Impact of stagnation time on lead levels at the tap

N=10 sampling events
pH 7.8±0.1,
Temperature 9.5±9°C
Alk 93±14 mgCaCO$_3$/L
11±8% particulate Pb



Impact of stagnation on Pb in large buildings: Variability within a single building



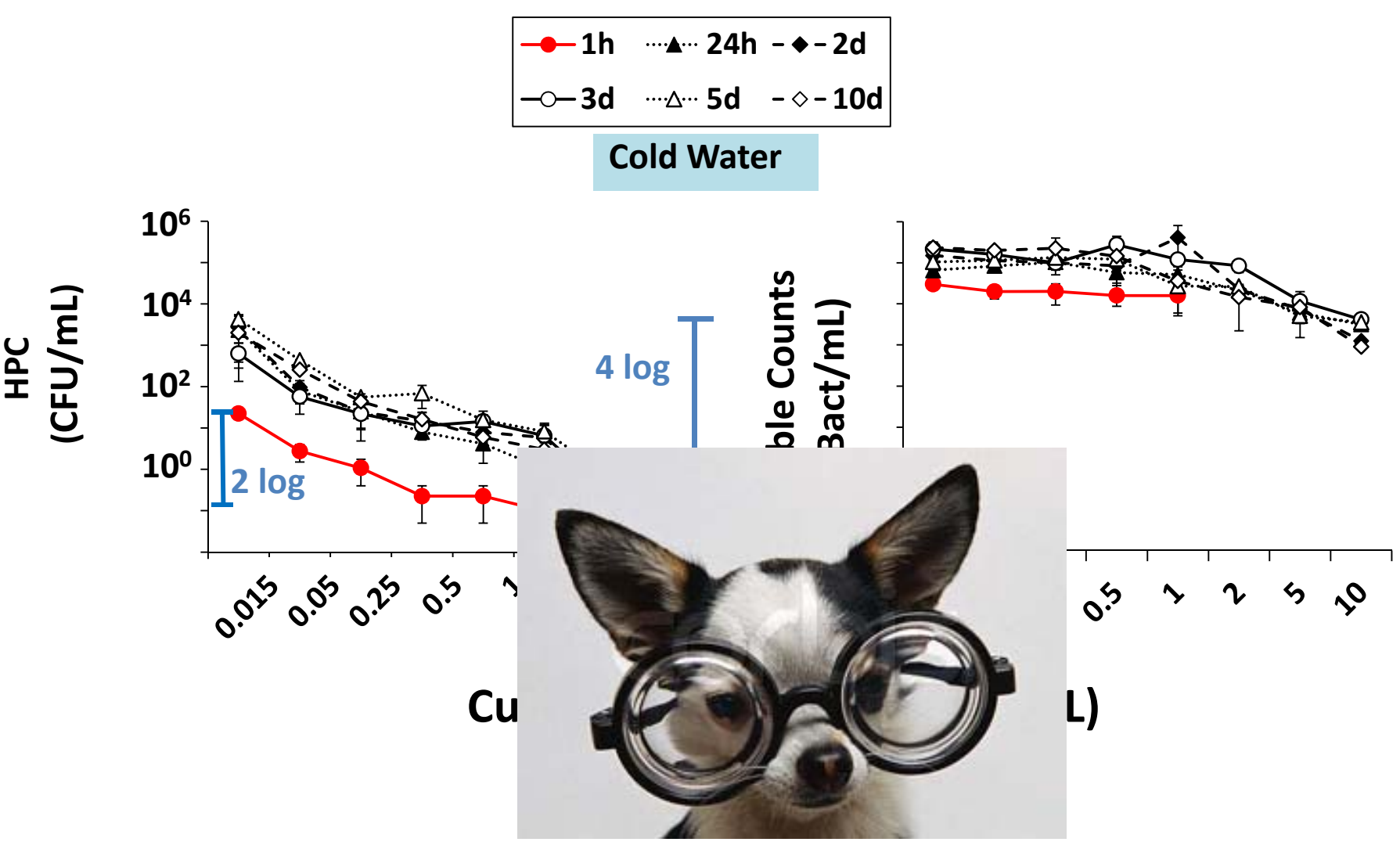


min	0.8
max	10100
mean	106
median	7.5
90th	117

Deshommes et al 2016

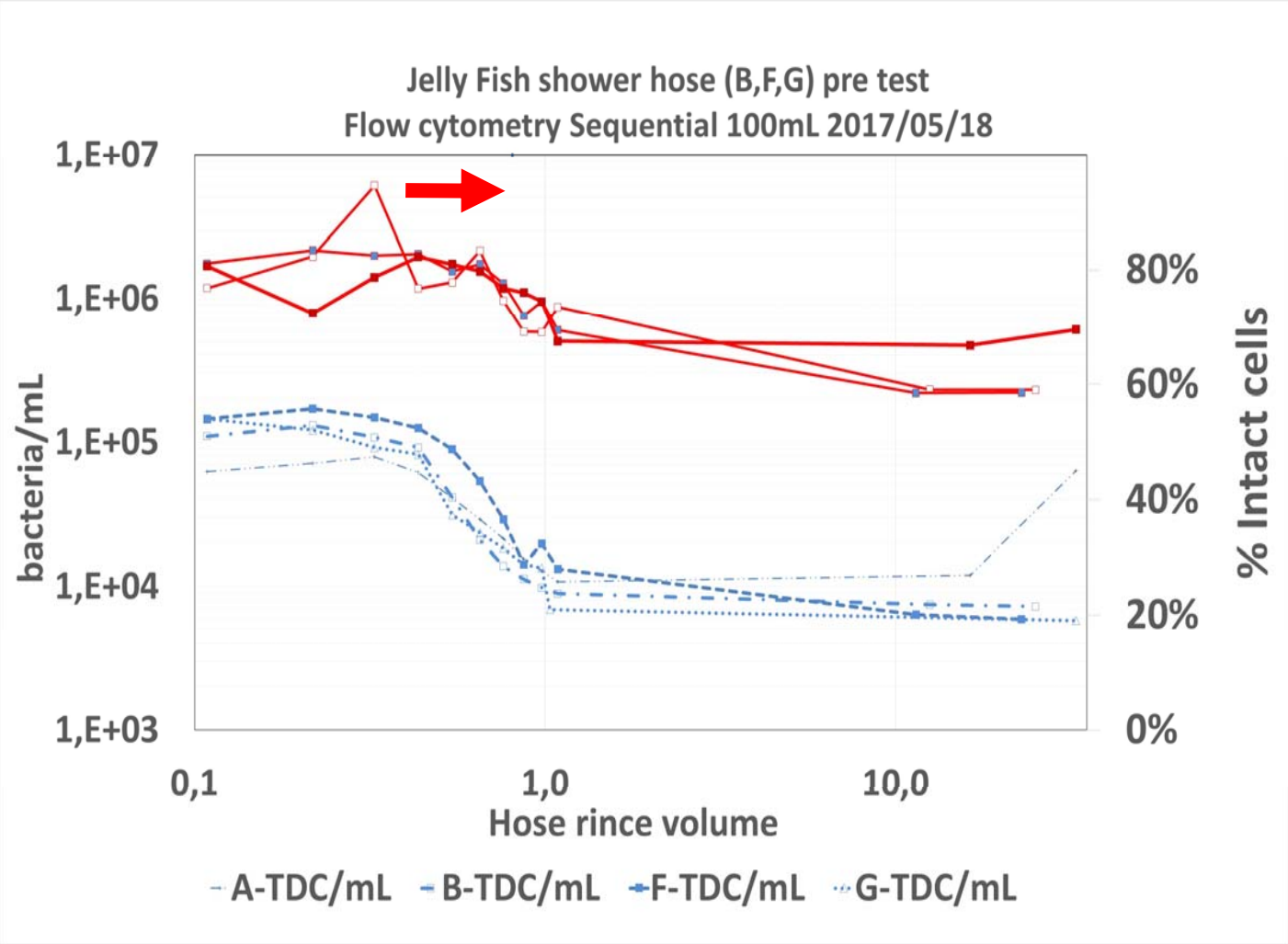
CANADIAN WATER NETWORK
RÉSEAU CANADIEN DE L'EAU

Stagnation promotes bacterial growth & detachment at taps



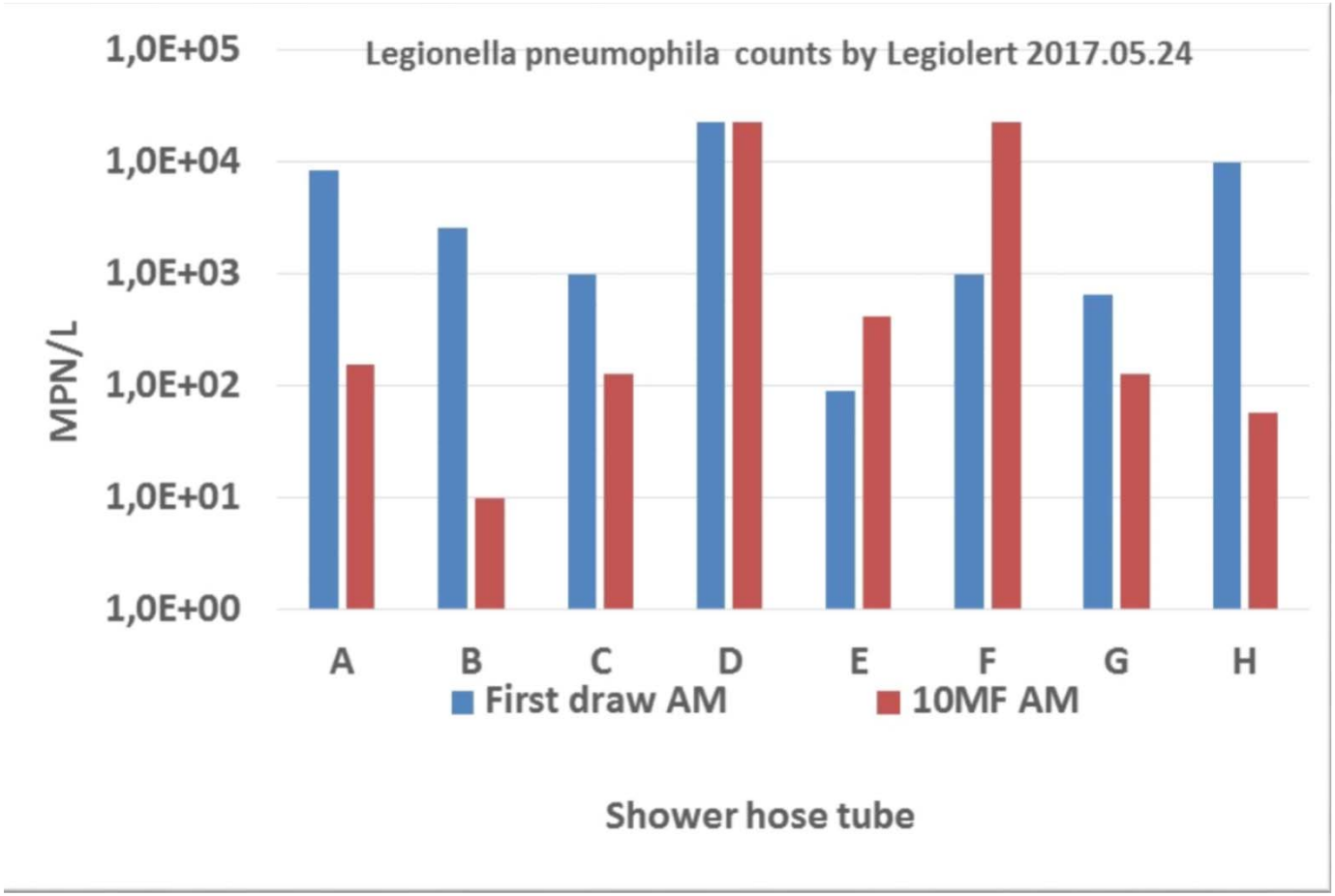
Stagnation in shower hoses
EAWAG 2017

Stagnation promotes bacterial growth & detachment – *EAWAG 2017*



Flow cytometry SB-PI

Stagnation promotes *Legionella pneumophila in PVC shower hoses EAWAG 2017*



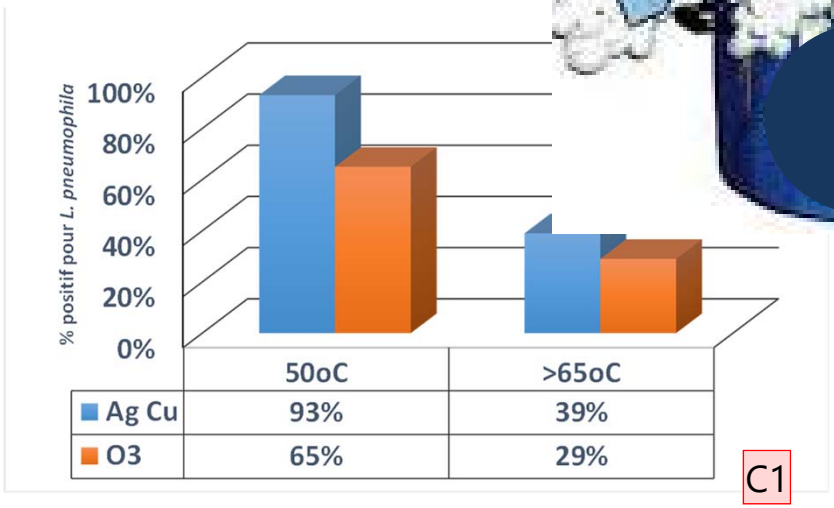
Common approaches to control Lp in HCFs

- **Maintenance of thermal regime**
  - Combination of > 60 °C & > 50/55 °C
- **Thermal shock**
  - 65-70°C for 30 min-24h
- **Hyperchlorination**
  - Poorly defined
- **Continuous chlorination**
- **Continuous *in situ* treatment**
  - Chloramines, Chlorine, Chlorine dioxide, Cu-Ag

Importance of preventive thermal treatment

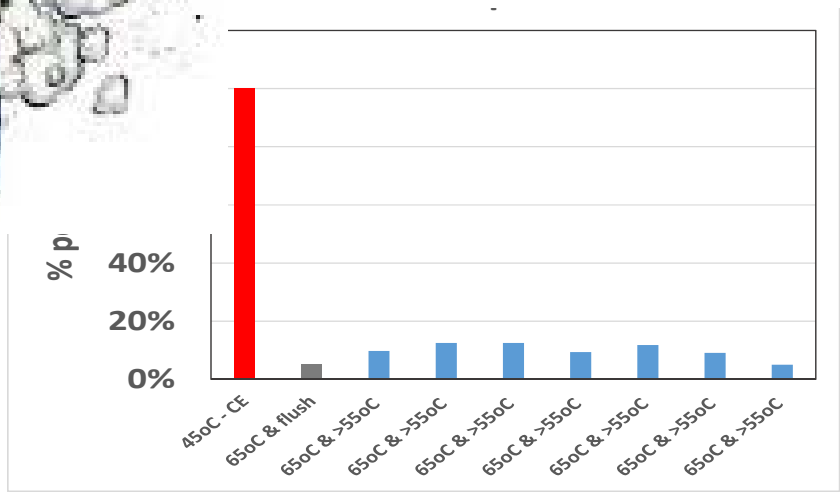
- Lowered temperature from 65°C to 50°C for energy conservation
- Addition of *in situ* Cu/Ag
  Hôpital de Lausanne CH
- 7 years of testing
- Lp control only at à 65°C

- *L. pneumophila* sg 1 outbreak (31 cases)
  temperature from 45°C to
  he heater and >55°C at the POU
  regime for 10 years = lower %
  taps & cases



C1

Blanc et al. 2005

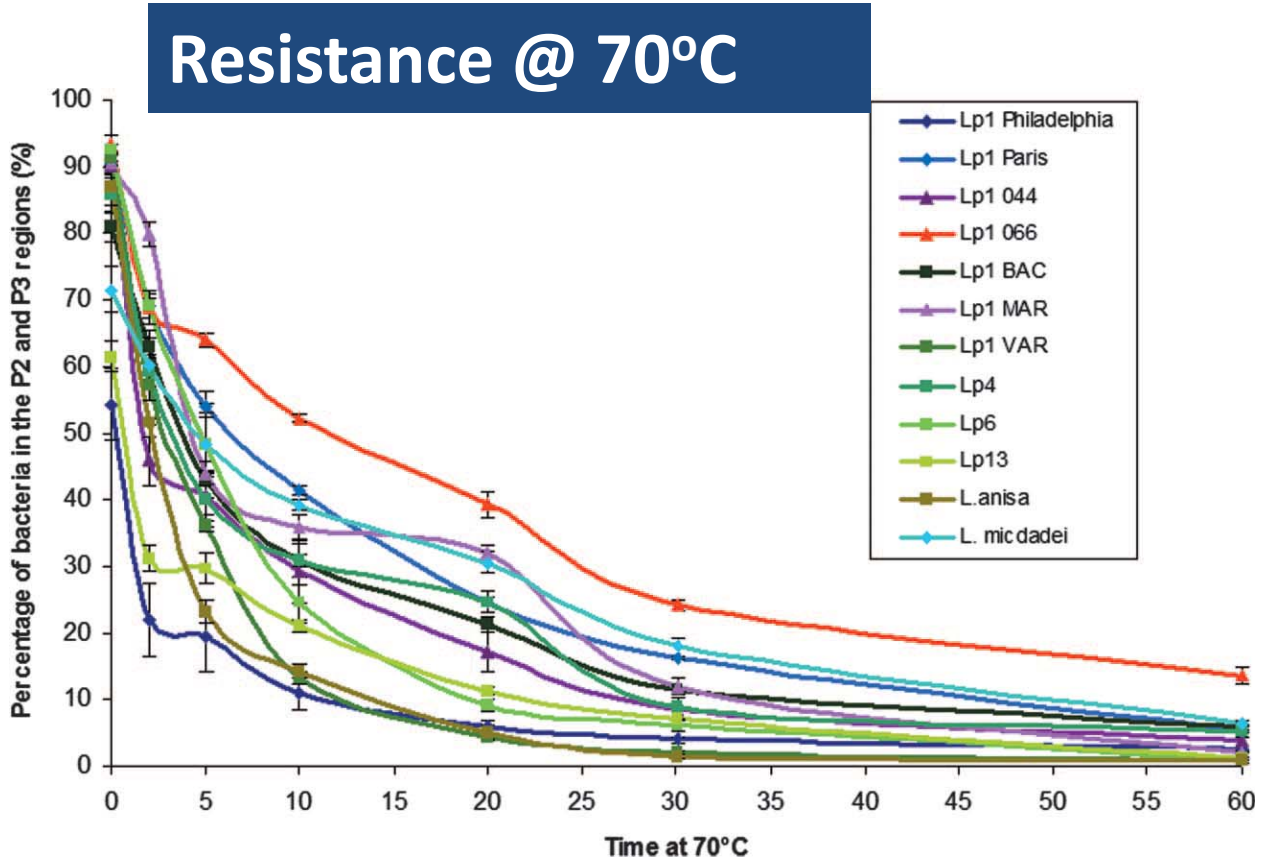


Darelid et al. 2002

Slide 18

C1 J'ajouterai des détails pour que l'information soit homogène avec le paragraphe des ECS
Cindy, 9/29/2013

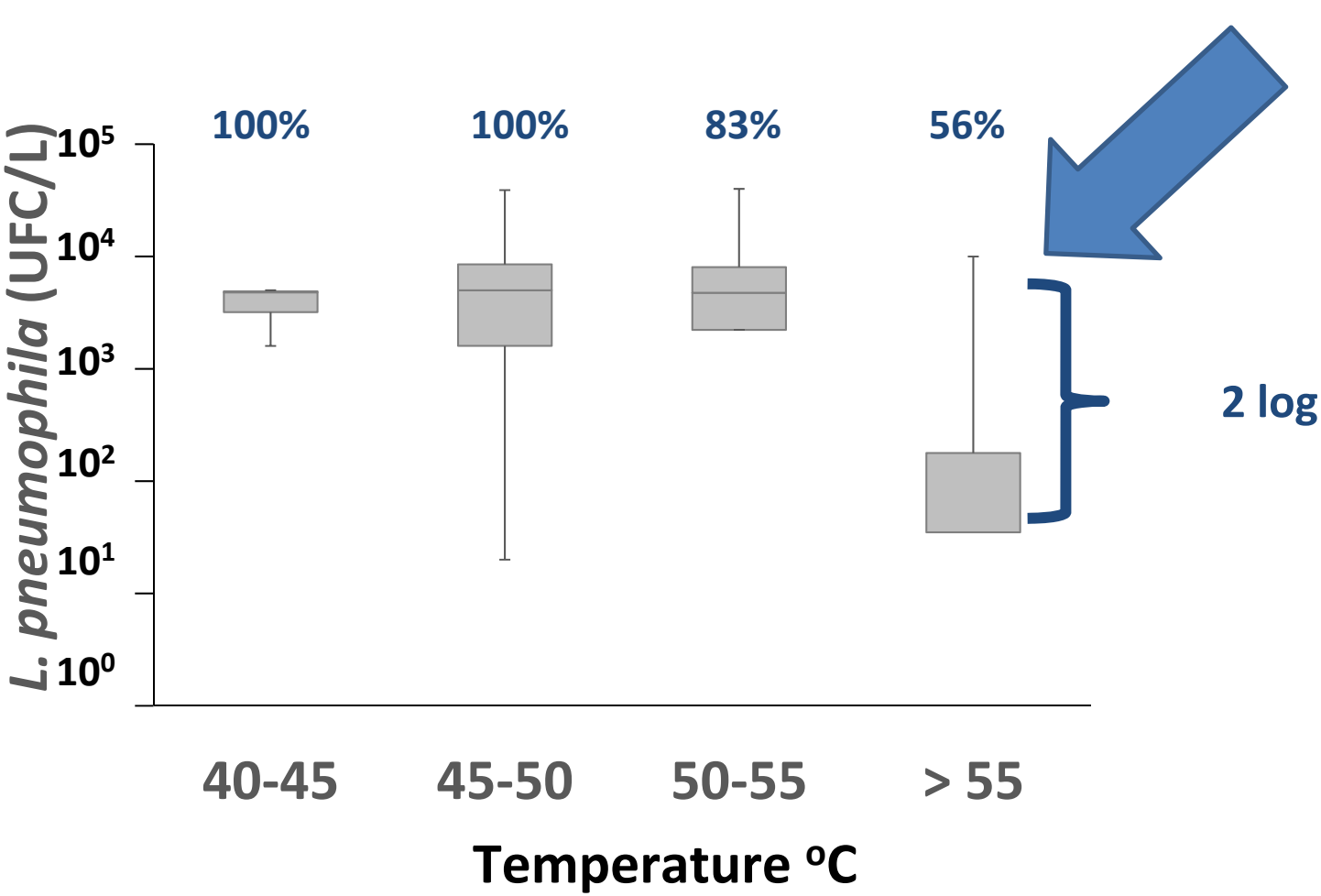
Resistance to temperature if preventive thermal regime is not maintained

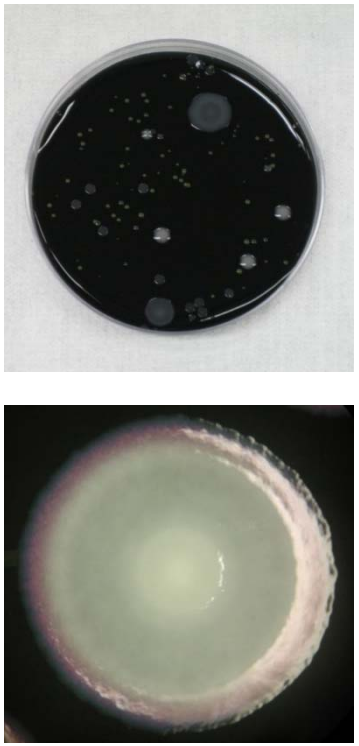


- **Inactivation of culturable + VBNC cells by flow cytometry**
- **Repeated thermal shock promotes resistance in HCF hot water systems**

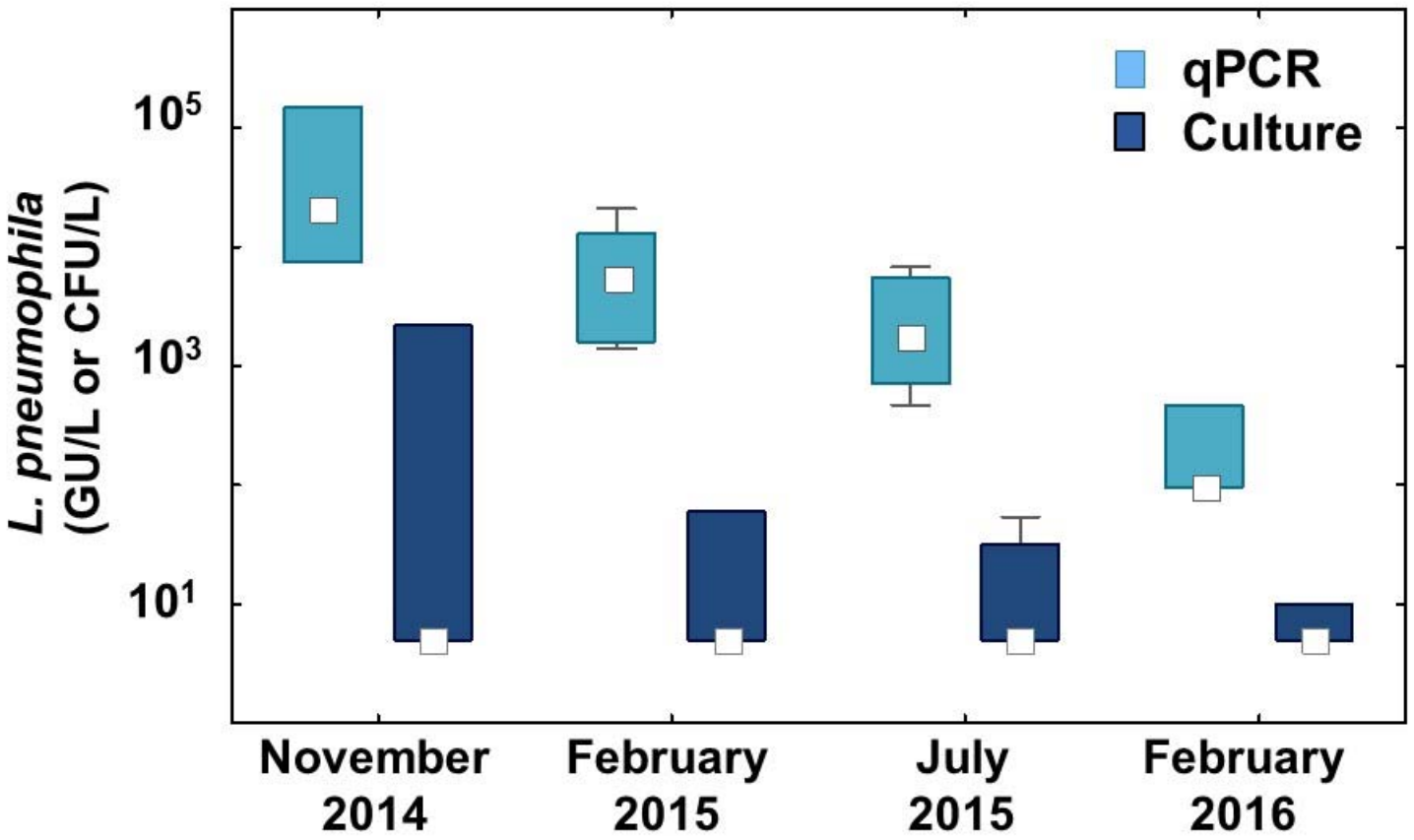
(Allegra et al 2008, 2011, Epalle et al, 2015)

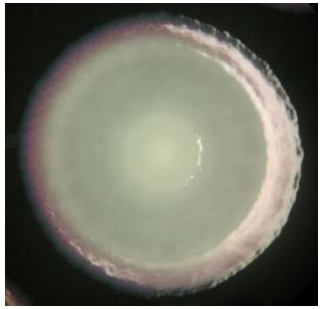
Effect of temperature at the tap positivity and culturable of *Lp* in pediatric hospital





Long term effect of corrective measures in HCF

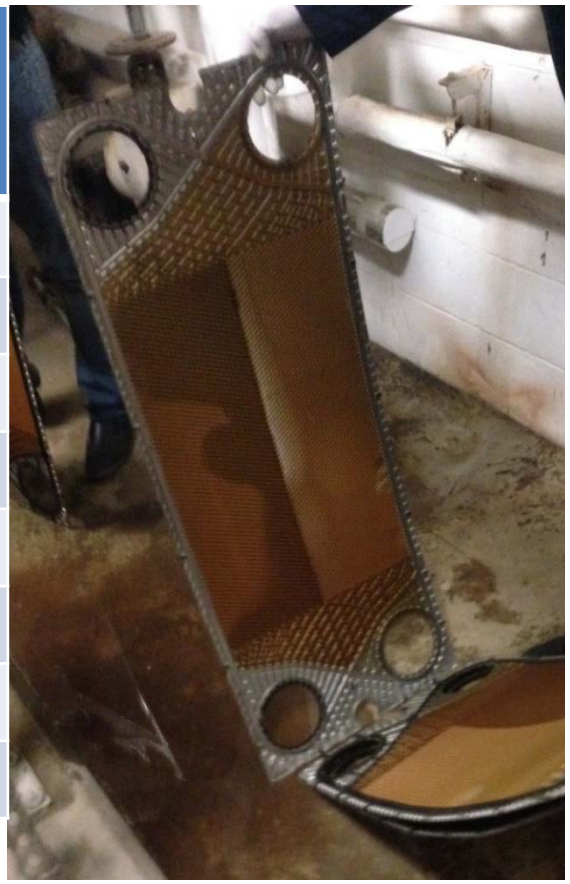




Clearly shows the progressive decrease of *Lp*

Wing A Heat Exchanger Contamination

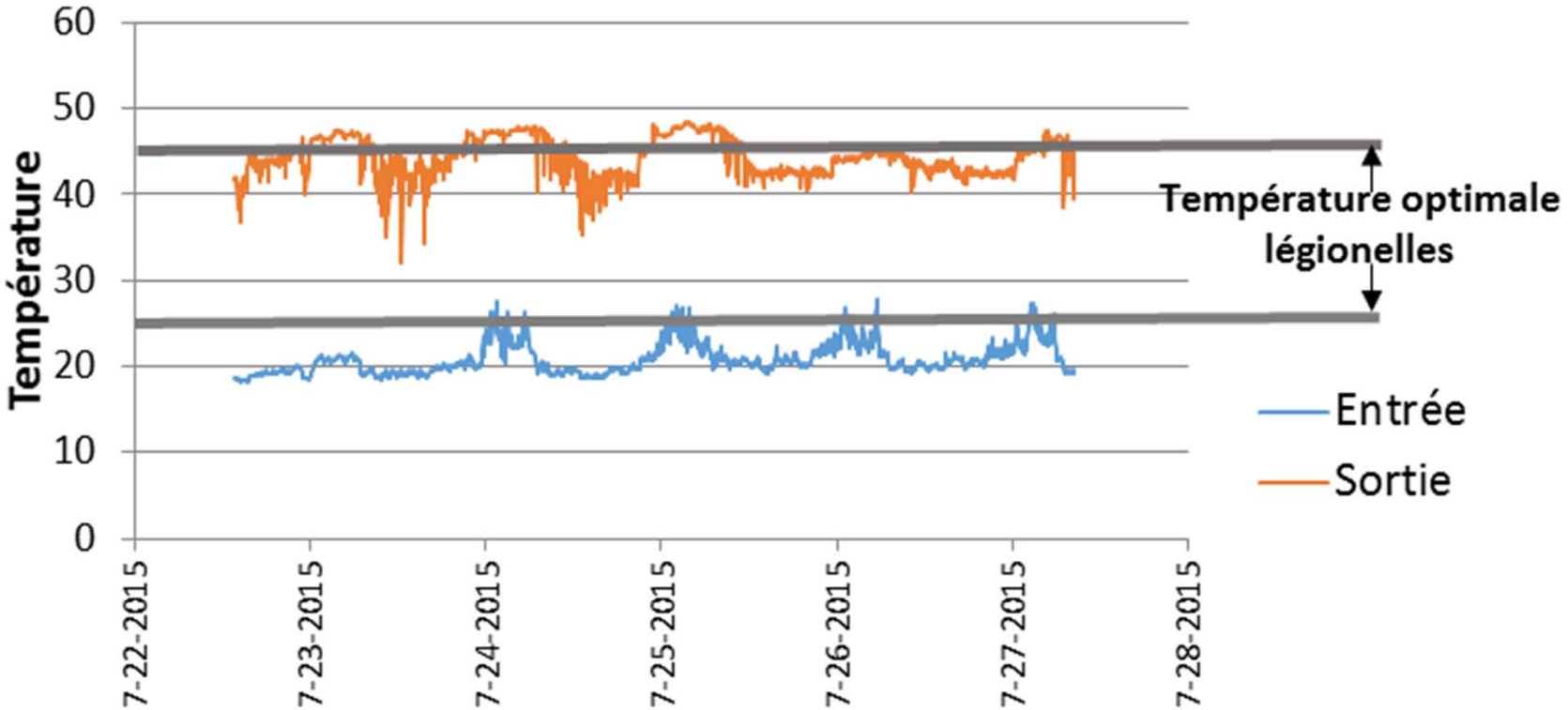
Sampling site	*L. pneumophila*	
	Culture (CFU/L)	qPCR (GU/L)
1st plate - swab	+	Positive
Middle plate - swab	+	Positive
Last plate - swab	< LD	< LD
Infeed pipe - swab	+++	Positive
Outfeed pipe - swab	++	Positive
Infeed pipe - water	510	4600
Outfeed pipe - water	88 000	85 000
Inside heat exchanger - water	5 000	22 000



+++ : > 10 000 CFU/swab; ++ : > 1 000 CFU/swab; + : < 1 000 CFU/swab

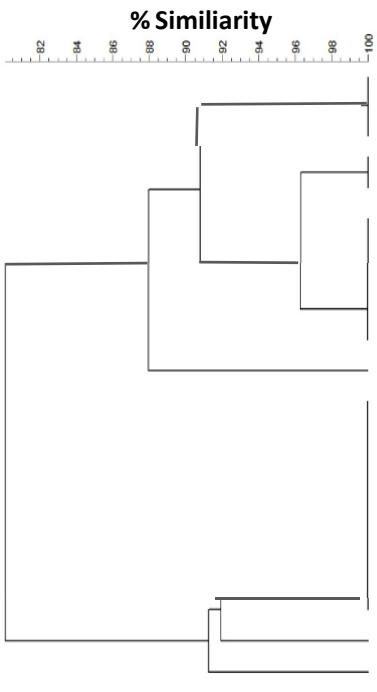
Bédard et al., 2016

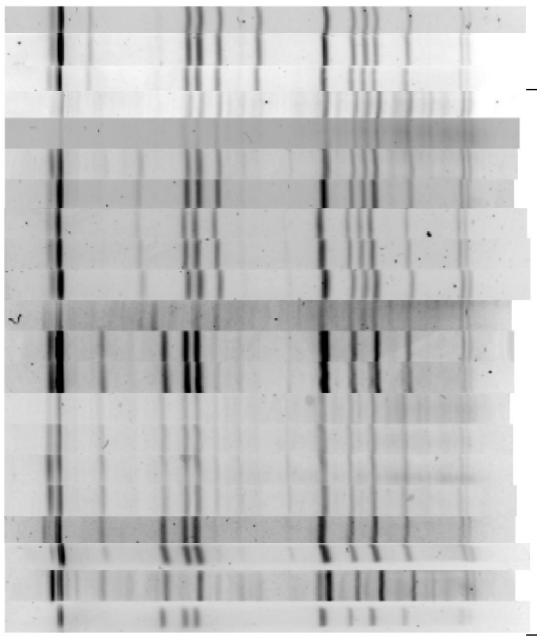
Temperature in heat exchanger pre heating makeup water



Strains genotyping

Genotyping *- PFGE (Tenover's criteria) Nested Sequence-Based Typing (DNA extracts)*





Wing	Sample Type	Device	SBT
	W	Sink	ST1427
B	W	Sink	
B	W	Bath	
A	W	Sink	ST1427
A	W		
A	B	Shower	ST1427
A	P		ST1427
A	W	Sink	
A	W	Sink	
A	W		
A	W	Bath	ST1427
A	W	Bath	ST1427
A	P		ST1427
A	W	Shower	ST1427
A	W	Bath	ST1427
A	W	Shower	ST1427
A	B	Sink	ST1427
A	W	Sink	
A	W	HeatEx	ST1427
A	W	Sink	ST1427
A	W	HeatEx	ST1427

: Water
: Biofilm
: Patient

Same strain isolated in the heat exchanger, in hot water and in clinical samples

Bédard et al 2016

Green buildings & infection control

Green buildings	SOLUTIONS	Infection prevention
Electronically activated faucets to reduce water consumption and minimize device contamination	Select faucets with minimal mixing volume integrated in the faucet body and stable materials	Avoid contact with first draw
	Higher minimal flow rate for electronic faucets in healthcare facilities	Maintain >6L/min Periodic flush at high T^{o}
Water conservation, to avoid wasting water	Short 250 mL flush (<10 s) before usage (*not practical with electronic faucets*)	Flush water before utilization (high bacterial load in distal volume)
	Minimize number of faucets to avoid low or no usage	Regularly flush low usage faucets
Installation of complex aerators to reduce flow rate	Select aerators of simple structure and biostable materials that can be disinfected or replaced	Avoid aerosolization Minimize surface available for biofilm
Heat exchangers	Redundancy for cleaning Only use when energy savings are significant No contact with recycle loop	Stringent periodic disinfection protocols with H&S precautions

Conclusion

- Green building pose new WQ challenges in terms of metals and pathogens
- Nutrients (BOM/N/P) and temperature remain the drivers for biofilm growth
- Better materials are a must – no toxic metals and biostable polymeric materials
- Renewed interest for biofilm control in large buildings driven by infection risk, especially in buildings with vulnerable populations
- Sampling volume, prior stagnation and analytical methods will define your ability to detect a problem and identify solutions


Bigger pipes:
Bigger problems!

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