Drinking Water Quality – pathogen prevention by controlling conditions inherent to the plumbing system

Thomas Kistemann
Bonn University (Germany)

ukb universitäts klinikumbonn

UNIVERSITÄT BONN

Institute for Hygiene and Public Health
ihph

Outline

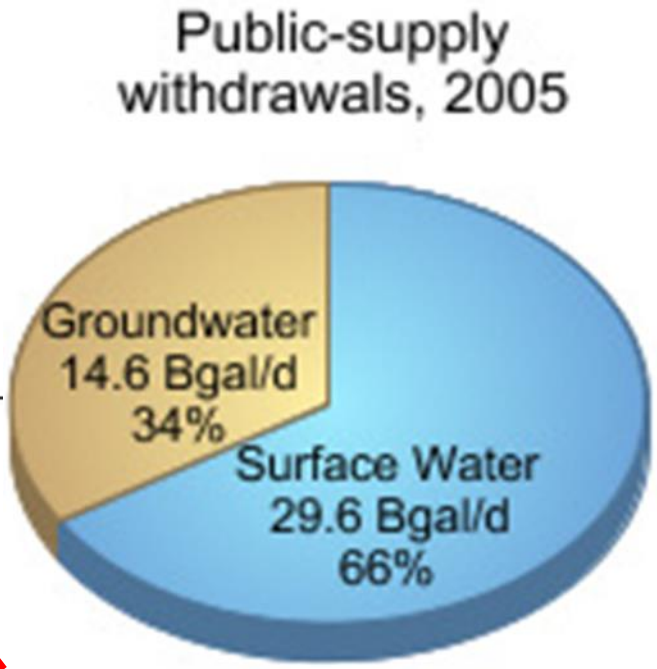
- **Drinking water hygiene**
- Ecology of microorganisms in drinking water plumbing systems
- Ecology of Legionella spp. in drinking water plumbing systems
- Consequences for of drinking water plumbing systems

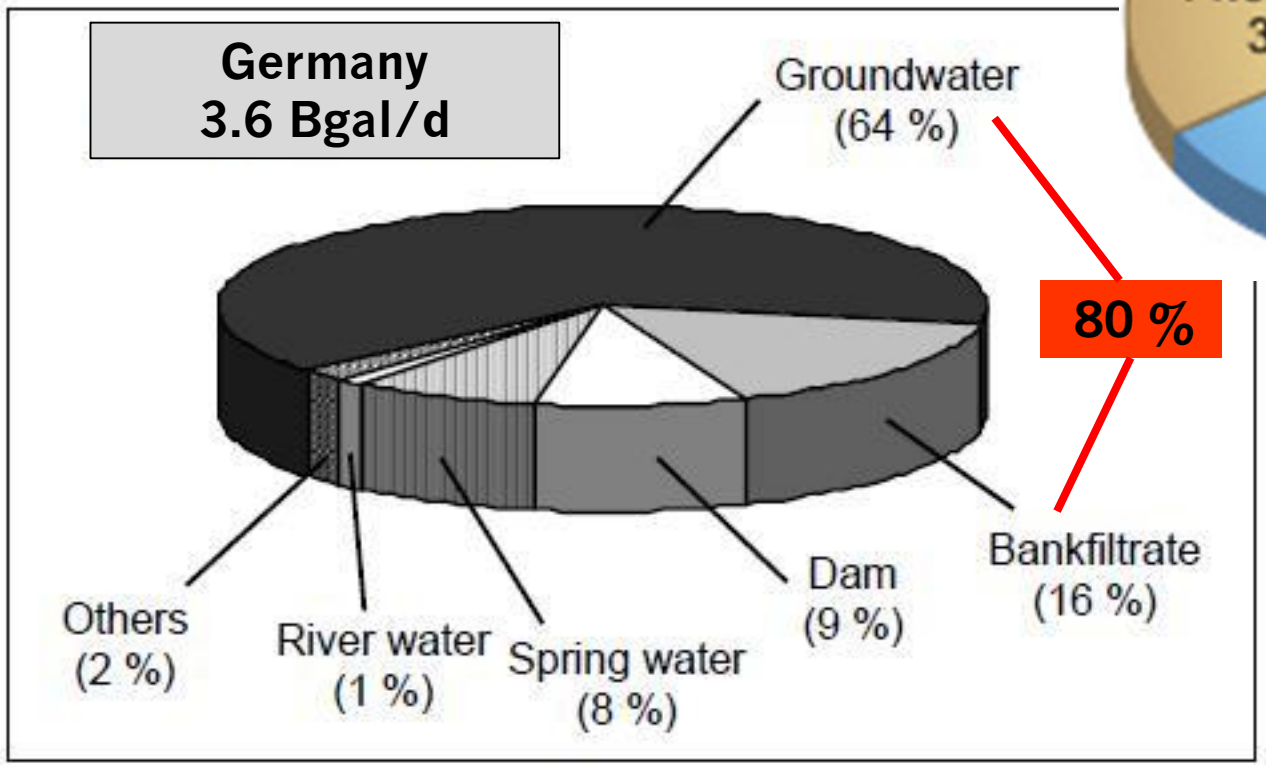
Hygienic drinking water quality – an ongoing issue

Or: Why do we have to address an issue which we considered to be solved yesterday (i.e. >100 years ago)?

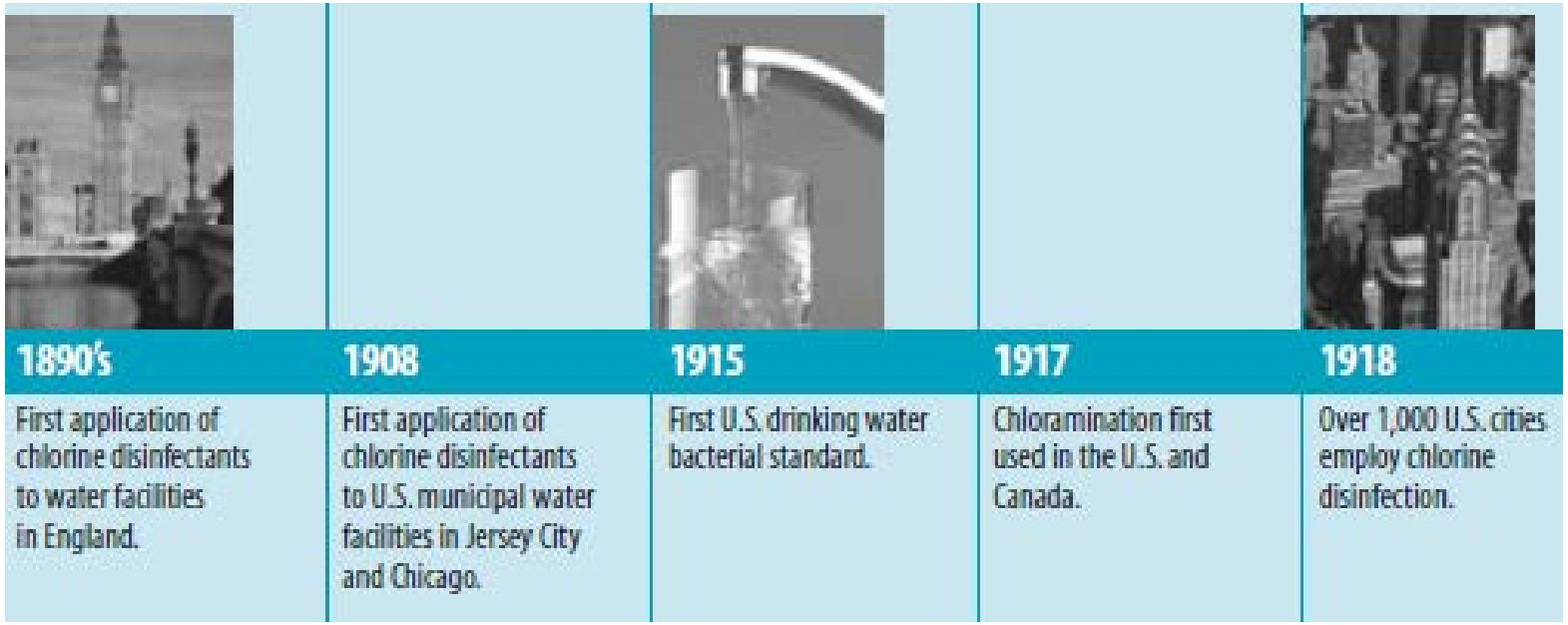
- enhancements of drinking water plumbing systems
- new utilizations (showers, whirl pools, ACs)
- in particular: domestic hot water
- changing user profiles, risk groups
- advanced investigation methods

Water abstraction: Europe – U.S.





DW disinfection



German Drinking Water Ordinance § 7 (3): Concentrations of chemical substances, which might unfavourably affect the quality of drinking water, have to be kept as low as possible

- max. concentration of free chlorine: **0.3 pp/l** (U.S.: 4 ppm)
- >70% of DW supply systems are run without any disinfection

Principles of drinking water hygiene

- Drinking water is not sterile
- Therefore: *Drinking water may not contain pathogens in concentrations which may impair human health.*
  (German Drinking Water Ordinance § 5,1)
- three criteria to assess health impact of pathogens:
  - Qualitative: **pathogenicity**
  - Quantitative: **concentration**
  - **Transmissibility** through water
- The microorganism needs to reach the drinking water, needs to be able to survive, and needs to be able to reach a human organ from the water which is sensitive to infection
- Drinking water may deteriorate in plumbing systems

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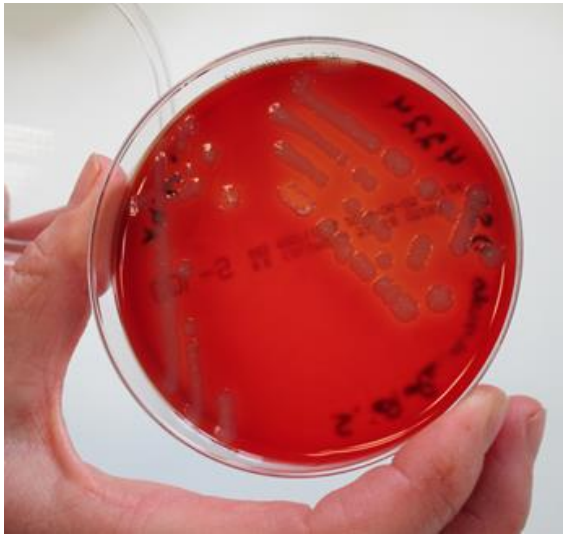
Microorganisms multiply in water

- Drinking water plumbing systems are inhospitable environments
- However even in these aquatic milieus an autochthonous microflora exists
- Including some potentially harmful microorganisms: Legionella, *Pseudomonas aeruginosa*, MOTT (mycobacteria other than tuberculosis)
- Things become more tricky – not sufficient to control microbial pollution entering from outside

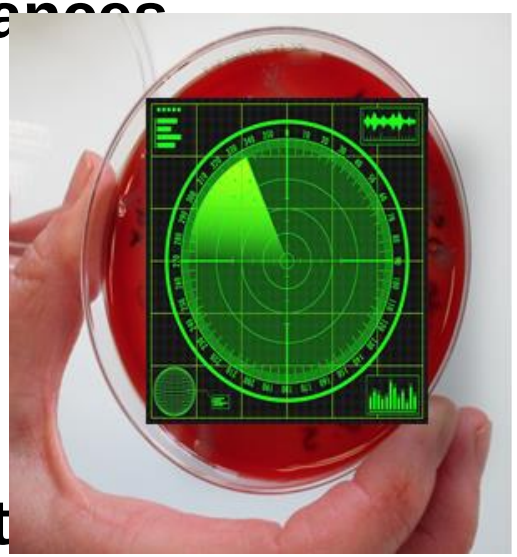
Microorganisms multiply in water

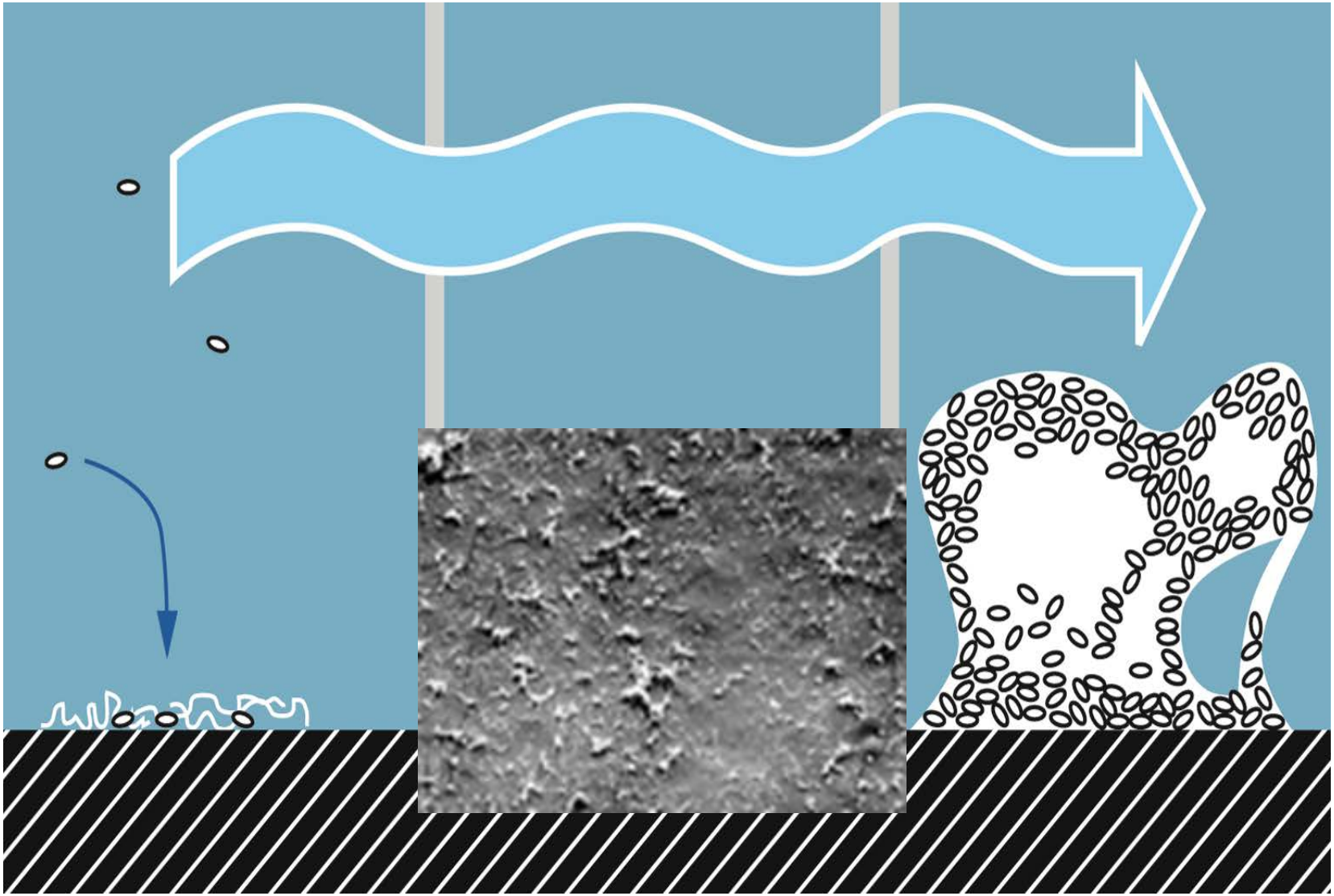
- The indicator principle fails!
  (no *E. coli* = no faecal contamination)
- A new question arises: Which **ecological conditions** favour survival, growth and replication of these pathogens in DW plumbing systems?
- Are pathogens able to develop specific forms of survival?
- Does this change their pathogenicity?



Bacteria disappear from the radar

- **Under stress, bacteria loose their ability to multiply, but remain alive, keep their cellular structure, may recover**
- **‚Viable but not culturable' - VBNC**
- **Stressors: lack of nutrients, osmotic pressure, O_2 pressure, pH, radiation, toxic substances, predators**
- **Reduced metabolic activity reduces sensitivity against external stressors**
- **VBNC is the normal form of life for the aquatic flora (99%)**
- **pathogens may migrate into VBNC stat**





Biofilms

- slime layers upon surfaces in regular contact with water
- contain microorganisms
- successful survival strategy of microorganisms
- Biofilm does not require much: microorganisms, water, some nutrient, a surface
- frame is produced by the microorganisms themselves
- organic and inorganic molecules embedded
- extremely heterogeneous environment (pH, O_2, nutrients, …)
- cell density exceeds density in the liquid phase (1:10,000)
- 95 % of DWPS microorganisms within the biofilm

Pathogens in biofilms

- **Typical biofilm flora is aquatic and not pathogenic, but:**
- **Availability of nutrients enhances microbiological mass, diversity, probability of pathogens to nest**
- **pathogens in DW Plumbing System biofilms:**
  - **Faecal pathogens (e.g. Salmonella)**
  - **Pseudomonas: pioneer settler**
  - **MOTT: pioneer settler**
  - **Legionella**

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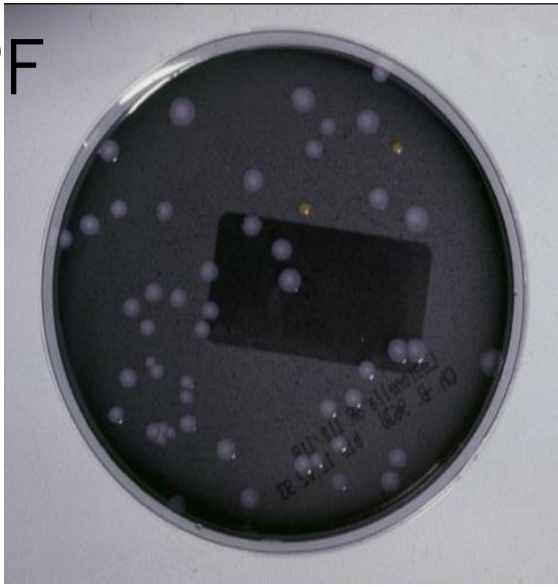
Legionella spec.

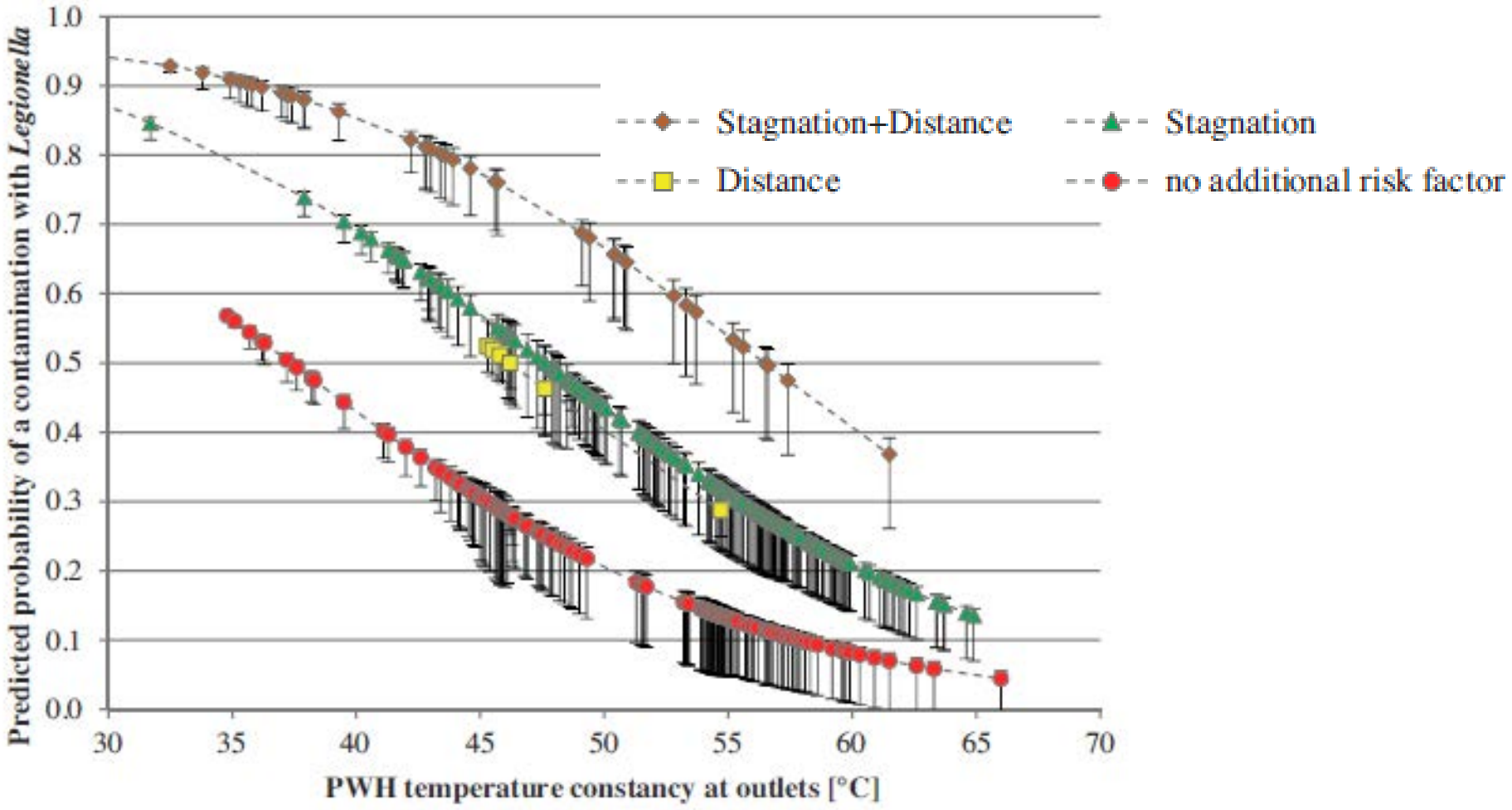
- 1976: 180/4,400 participants of a veterans‘ meeting in Philadelphia got pneumonia; 29 died
- agent: *Legionella pneumophila* (isolated in 1977)
- organism of a new ecological niche: domestic hot water
- multiplication possible at 82-132°F
- Infection via inhalation
- Diseases: Legionellosis / Pontiac Fever



Legionella spec.

- 20,000-30,000 annual cases of Legionnaire's disease in Germany
  (infection rate: 3-4 cases / 100,000 persons)
- Infection sites: 1. private environment (>50%)
  2. hotels
  3. medical care institutions
- Much more frequent: Pontiac fever
- Not indicated by *E. coli* etc. in drinking water
  New parameter in DWPS required
- Technical Action Value (TAV): ≥100 cfu/100ml

Influence of environmental factors on Legionella concentrations in DWPS



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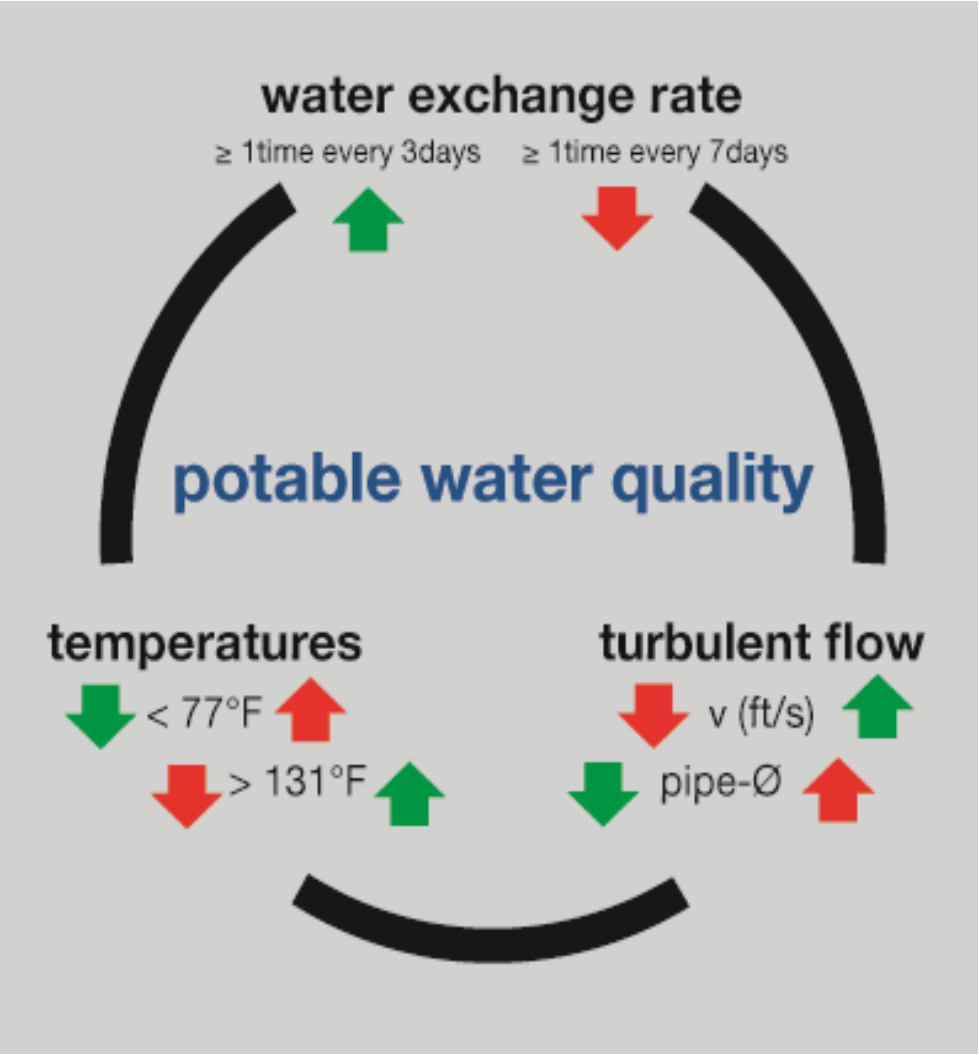
Consequences

- **Drinking water plumbing systems are microbiological eco-systems – ecological perspective necessary**
- **Parameters** to be considered:
  - temperature
  - time
  - shearing forces
  - Nutrients (plumbing material, water quality)
- **Biofilm and VBNC protect pathogens from chemical and physical disinfection measures**

In Practice

- **Avoid temperature optimum of human pathogens (75-131° F)**
- **Ensure water dynamics: water exchange + flow**
  - **Water exchange controls time for multiplication**
  - **Turbulent flow reduces laminar boundary layer**
  - **low stagnation, high water exchange!**
- rather **quality control of processes** than quality control of the product at point of use

Circle of impact on DW quality



New Requirements for DW Quality

According to German Drinking Water Ordinance since 2011:

1. **Additional microbiological routine parameter: *Legionella* spec.**
   Technical Action Value: > 100 cfu/100ml
2. **the commonly accepted technical standards (temperature regimes, residual times, materials, flow rates, etc.) have to be fulfilled**

“Bring Hunter into the 21th century”

- Hunter (1940) considered a plumbing fixture’s water flow (toilet), duration of flow, and the 99th percentile probability that multiple toilets would be flushing simultaneously
- It’s simplicity is seductive but it’s also way too conservative and greatly oversizes supply and waste lines
- **American Council for an Energy Efficient Economy Hot Water Forum** (2013): tackling revisions to H Curve
- **IAPMO Taskgroup**: “Bring Hunter into the 21th century”
- IAPMO/ANSI 2018 **Uniform Plumbing Code**: Appendix M: Peak Water Calculator

International Association of Plumbing and Mechanical Officia

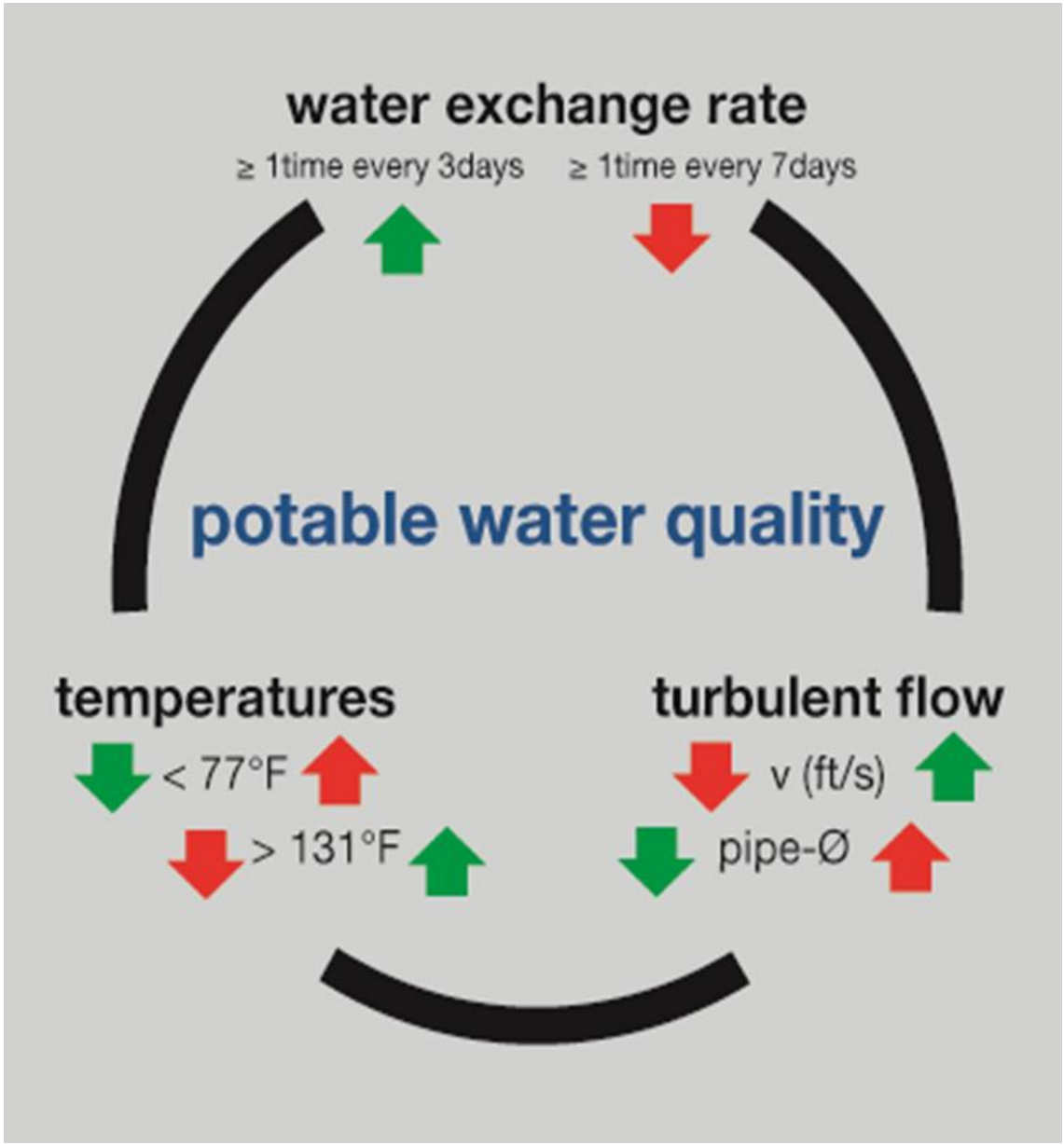
Management Tool: Water Safety Plan

- **end point control is not sufficient** for DW quality management
- World Health Organization: **critical control points** (CCP) need to be defined and surveyed: temperature, stagnation, flow, nutrients, …
- **process control** complements product control
- **WSP for buildings** follow the common rules of procedure of an iterative process:

description – assessment – management – monitoring – verification

Summary

- **Human health:**
  Top priority objective for Drinking Water Quality
- **Chemical (chlorine etc.) and physical (thermal, UV) disinfection has limited effect due to biofilm and viable but non culturable (VBNC) pathogens**
- **Manage accordingly to Water Quality Circle**
  - **Temperature**
  - **Water exchange**
  - **Turbulent flow**
- **Use of high quality plumbing components**
- **Management tool: Water Safety Plan concept**



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Thank you!