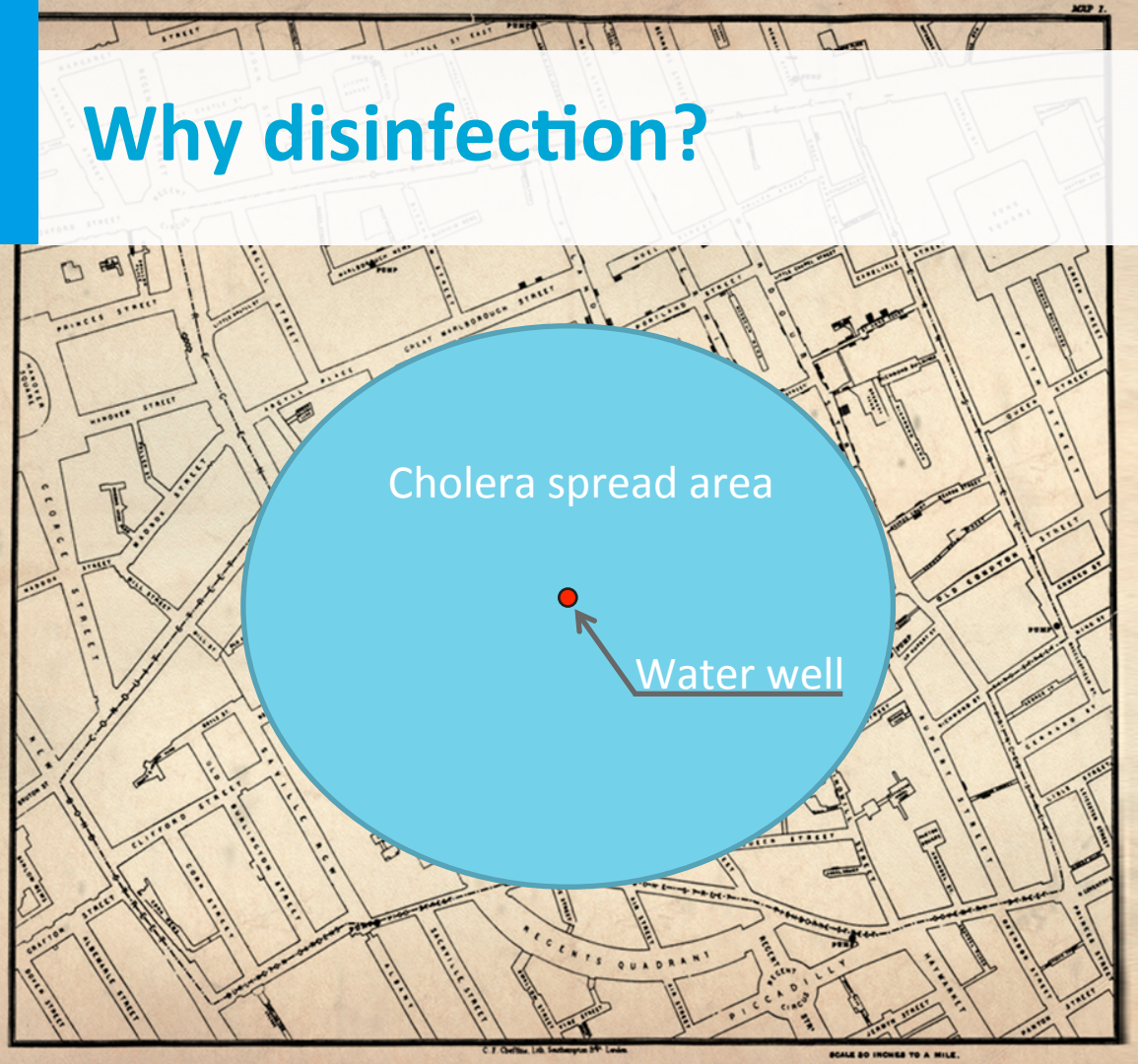
Why disinfection?



Disinfection

CTB3365x Introduction to water treatment

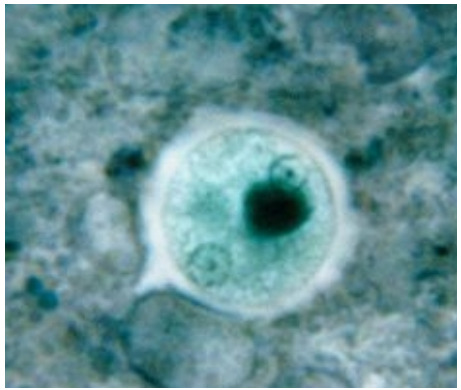
Prof. dr. ir. Luuk Rietveld – Urban Water Technology

This lecture

- Why disinfection?
- Theory of disinfection
- Different types of disinfection

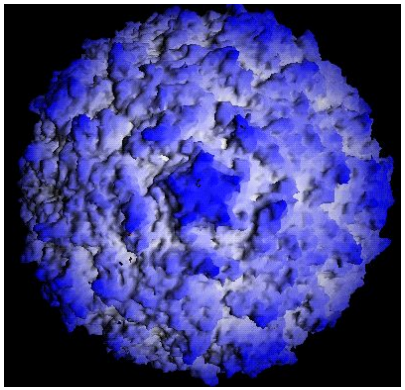
Objective of disinfection

Protozoa



Bacteria

Viruses



- Inactivation/removal of pathogenic microorganisms
- Prevention of (re)growth

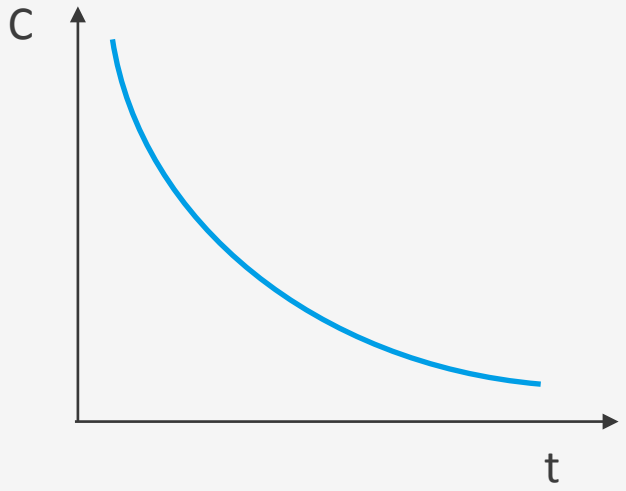
Disinfection mechanisms

- Oxidation or rupturing cell wall
- Diffusion into cell
- Damaging DNA

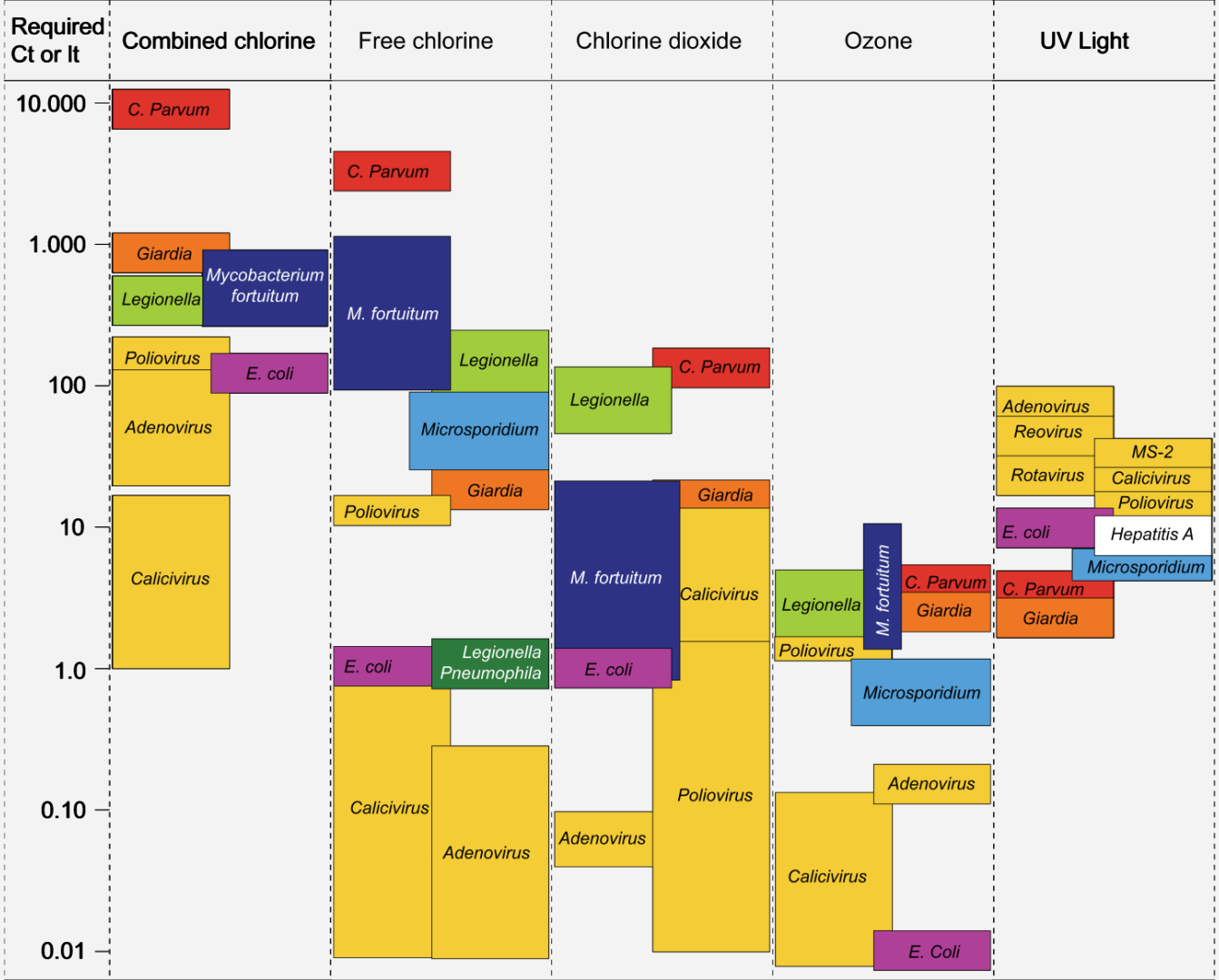
Disinfection kinetics (reaction rates)

Chick – Watson:

$$\ln\left(\frac{N}{N_0}\right) = -K_{CW} \cdot C \cdot t$$



N	Number microorganisms [CFU/100 ml]
N_0	Initial number microorganisms [CFU/100 ml]
K_{cw}	Specific lethality [l/(mg·s)]
C	Concentration [mg/L]
t	Time [s]


Required Ct or It
Combined chlorine
Free chlorine
Chlorine dioxide
Ozone
UV Light
10.000
1.000
100
10
1.0
0.10
0.01
C. Parvum
Giardia
Legionella
Mycobacterium fortuitum
Poliovirus
E. coli
Adenovirus
Calicivirus
C. Parvum
M. fortuitum
Legionella
Microsporidium
Giardia
Poliovirus
E. coli
Legionella Pneumophila
Calicivirus
Adenovirus
Legionella
C. Parvum
M. fortuitum
Giardia
Calicivirus
E. coli
Adenovirus
Poliovirus
Legionella
M. fortuitum
C. Parvum
Giardia
Poliovirus
Microsporidium
Calicivirus
Adenovirus
E. Coli
Adenovirus
Reovirus
Rotavirus
MS-2
Calicivirus
Poliovirus
E. coli
Hepatitis A
Microsporidium
C. Parvum
Giardia

Disinfection kinetics (reaction rates)

Disinfection kinetics depend on:

- Type of microorganism
- Type & concentration of disinfectant
- Temperature
- pH

Disinfection efficiency depends on:

- Reaction rates
- Water matrix (e.g. Natural Organic Matter & NH_4)

Disinfection methods

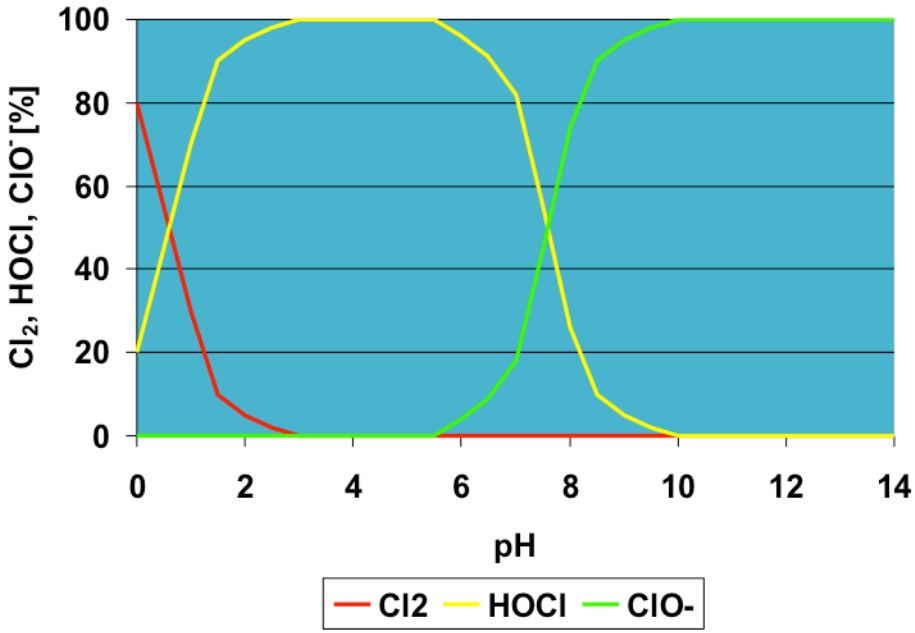
Chlorination

Application: chlorine gas or sodium hypochlorite

$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$

$HOCl \leftrightarrow H^+ + OCl^-$

Cl_2= chlorine gas
HOCl = hypochlorous acid
OCl^- =hypoclorite



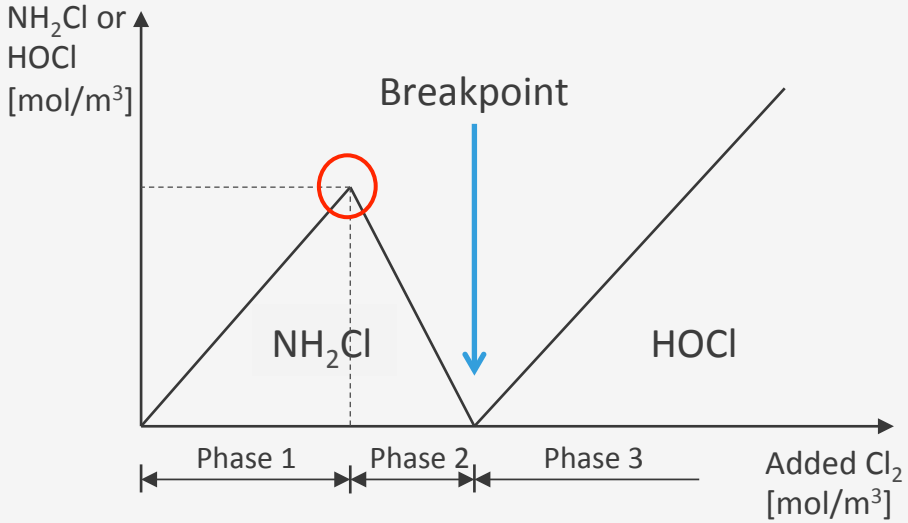
Effects chlorination

Organic compounds → disinfection by-products:

- Trihalomethanes
- Haloacetic acids

Inorganic compounds:

- NH_4^+
- Breakpoint chlorination



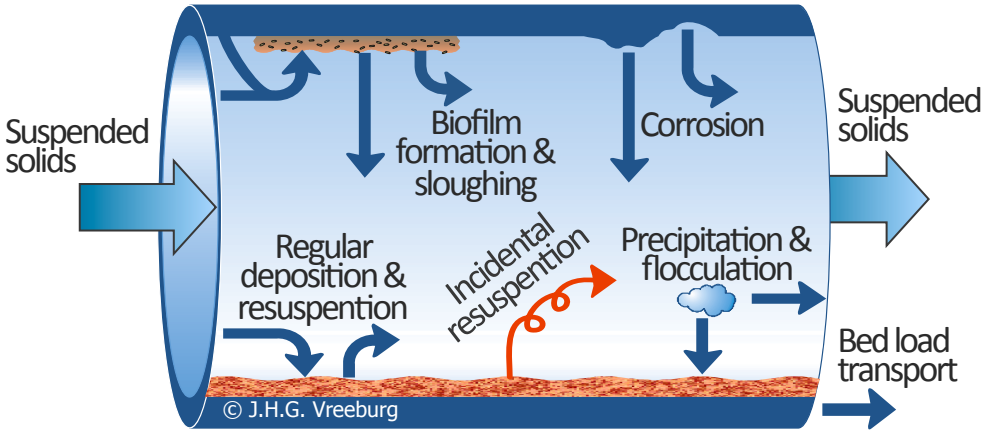
$$NH_4^+ + HClO \longrightarrow NH_2Cl + H_3O^+$$

$$2NH_2Cl + HClO + H_2O \longrightarrow N_2 + 3H_3O^+ + 3\,Cl^-$$

Advantages & disadvantages chlorination

Advantages:

- Residual prevents recontamination & regrowth



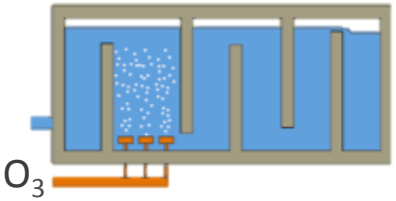
Disadvantages:

- Not effective for protozoa
- Danger of handling chlorine
- Formation of disinfection by-products (DPB)

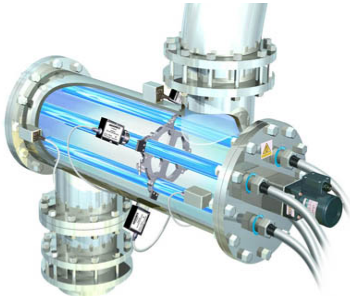
→Dutch approach: disinfection without chlorine

Alternative types of disinfection

Ozone (O_3)

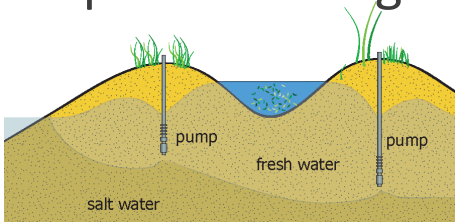


UV-radiation



Slow sand filtration

Managed aquifer recharge

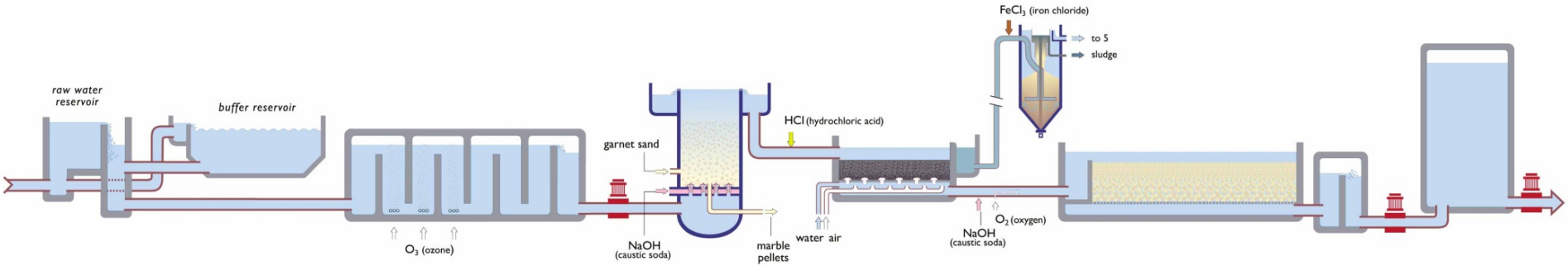


Membranes

Differences disinfection methods

	Chlorine	Ozone	UV	Slow sand filtration
Operation	Easy	Difficult	Difficult	Easy
Costs	Low	Moderate	High	High
Effective for protozoa	No	Yes	Yes	Yes
DBP	Yes	Yes	No	No
Residual	Yes	No	No	No

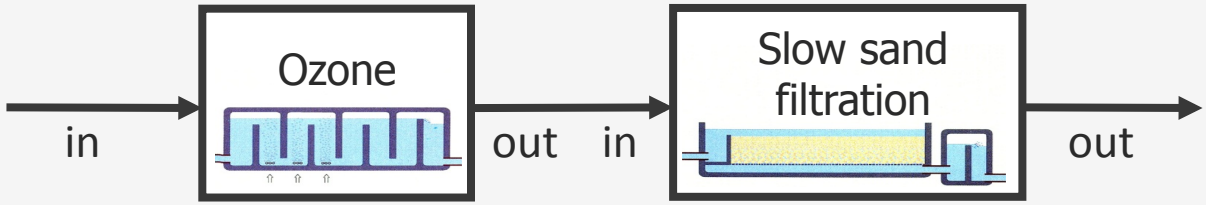
Multi-barrier system



Log Reduction Value (LRV)

$$LRV = \log(in) - \log(out) = \log\left(\frac{in}{out}\right)$$

1 log = 90%
2 log = 99%
3 log = 99.9%
4 log = 99.99%



E.coli [N/L]

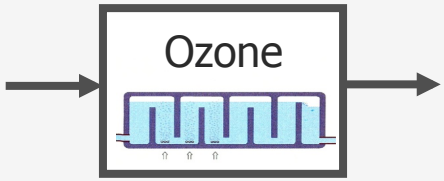
1200000 | 478 | 95

LRV [-]

$$\log\left(\frac{1200000}{478}\right) = 3.4 \quad + \quad \log\left(\frac{478}{95}\right) = 0.7 \quad = 4.1$$

Design

- Plug flow instead of complete mixing
- Avoid short-circuiting
- Bypassing causes a dramatic reduction in disinfection



	%	in [N/L]	out [N/L]	LRV
Ozone	99	1,200,000	478	3.4
Bypass	1	1,200,000	1,200,000	0
Total	100	1,200,000	12,478	2.0

Distribution without chlorine

- No nutrients for regrowth
- No leakage during transport & distribution
- Sufficient pressure in the network

Only place where we still allow chlorine in water…

Disinfection

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