Section 5.2
Factors of Disinfection

- Contact time
- Concentration of disinfectant
- Temperature

1. Contact time

Given a constant concentration of disinfectant, the reduction rate of microorganism concentration is linearly correlated to the concentration of microorganisms

Chick's law

(1908)

$$\frac{dN_t}{dt} = -kN_t$$

Integration

$$\frac{N_t}{N_0} = e^{-kt}$$

$$\ln\frac{N_t}{N_0} = -kt$$

(In usual logarithm)

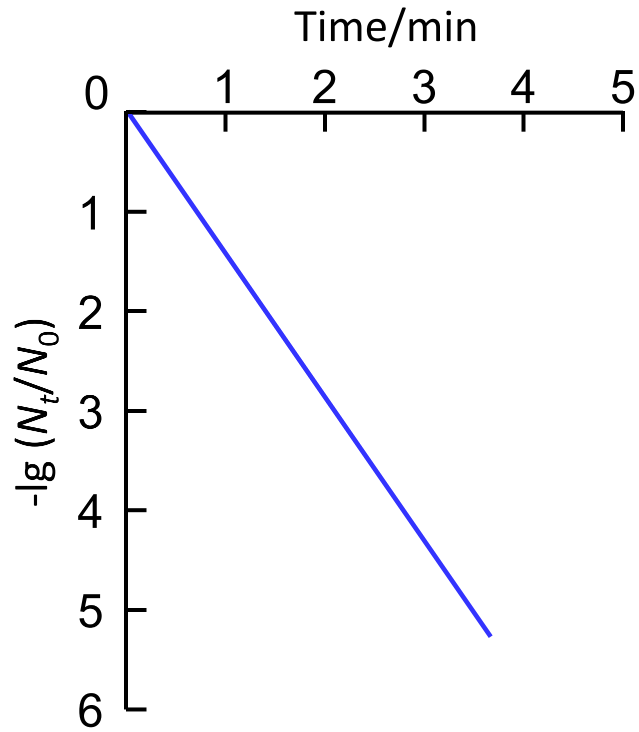
$$\lg\frac{N_t}{N_0} = -\frac{kt}{2.303}$$

(In natural logarithm)

N_t: Concentration of microorganism at time t

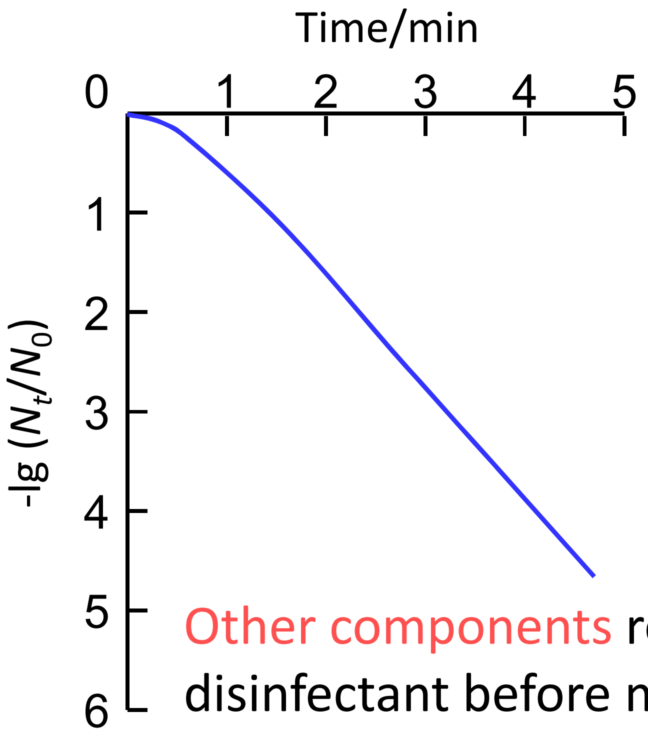
k: Inactivation rate constant

t: Reaction time



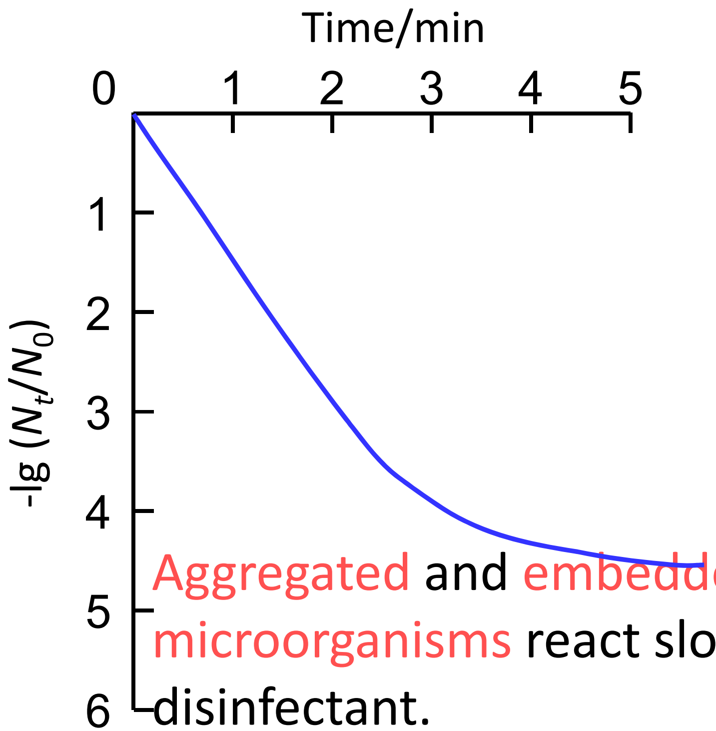
1. Contact time

Practical inactivation curve



Other components react with disinfectant before microorganism

Curve hysteresis



Aggregated and embedded microorganisms react slowly with disinfectant.

Curve smearing

2. Concentration of disinfectant

Relation between inactivation rate constant and concentration of disinfectant:

$$k = k'C^n$$

k': die-off constant

C: disinfectant concentration

n: dilution coefficient

$$\frac{dN_t}{dt} = -kN_t$$

Chick law

$$\frac{dN_t}{dt} = -k'C^n N_t$$

Chick-Watson law

Integration

$$\frac{N_t}{N_0} = e^{-k'C^n t}$$

For a certain inactivation level, $C^n t$ is a constant.

Logarithm

$$\ln\frac{N_t}{N_0} = -k'C^n t$$

$$\lg\frac{N_t}{N_0} = -\frac{k'C^n t}{2.303}$$

Logarithm

$$\lg C = -\frac{1}{n}\lg t + \frac{1}{n}\lg\left[\frac{2.303}{k'}\left(-\lg\frac{N_t}{N_0}\right)\right]$$

Given a certain inactivation ratio, on log-log plot, C is linear with t, and the slope is n.

2. Concentration of disinfectant

C^nT: → CT

- n=1 — C and t are equally influential
- n>1 — C is more influential
- n<1 — t is more influential

Normally n is assumed as 1.

C: Residual concentration of disinfection, mg/L
T: Contact time.
(t_{10}: contact time that 90% water in clean-water reservoir can achieve)

For certain inactivation ratio, "$C \cdot t$" is a constant.

- Index of the performance of disinfectant.
- Changes with disinfectants, microorganisms, temperature, pH, et al. (For a certain inactivation requirement)
- The smaller CT is, the better the disinfectant is. (For a certain inactivation requirement under same conditions)

2. Concentration of disinfectant

CT values for 99.9% inactivation of Giardia

Temperature	5°C	10°C	20°C
2 mg/L free chlorine （pH=7）	165	124	62
Chlorine dioxide	26	23	15
Ozone	1.9	1.4	0.72
Chloramines	2200	1850	1100

CT:

Ozone < Chlorine dioxide < Free chlorine < Chloramines

Disinfection ability:

Ozone > Chlorine dioxide > Free chlorine > Chloramines

2. Concentration of disinfectant

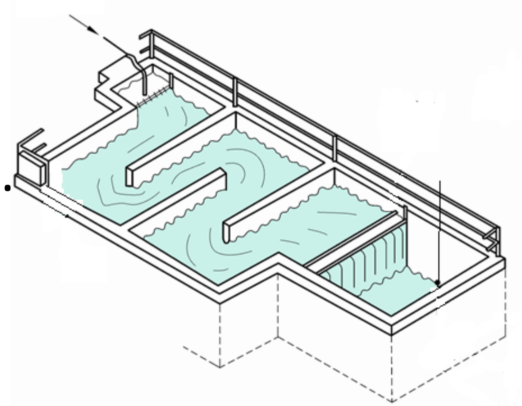
Contact time t_{10}

Clean-water reservoir in water plant is usually used to meet the requirement of contact time after the disinfectant is dosed

↓

Flow isn't ideal plug flow.

Part of the water has less retention time than the average.



↓

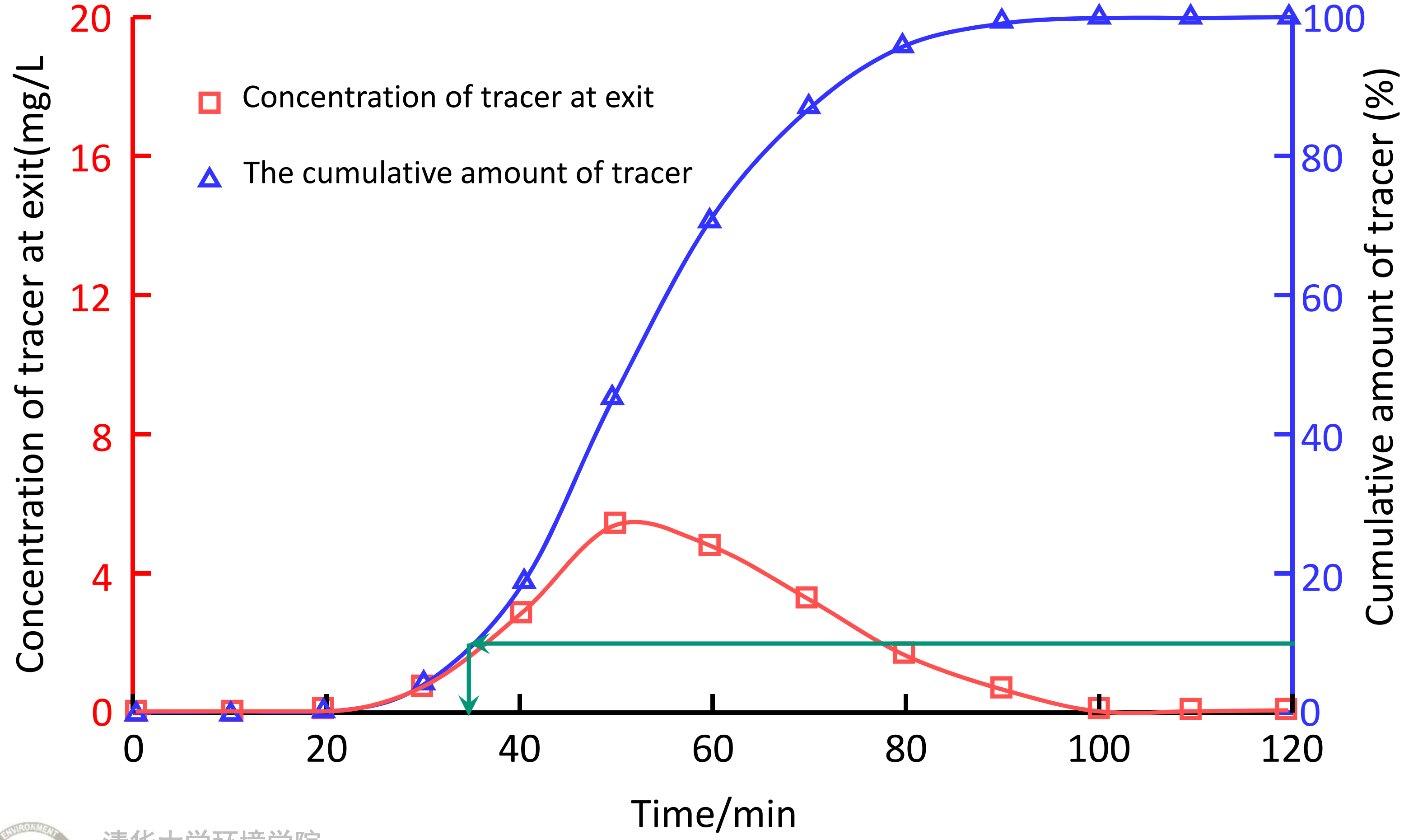
Design of clear-water reservoir should ensure **90% water** in it **meet the required retention/contact time**.

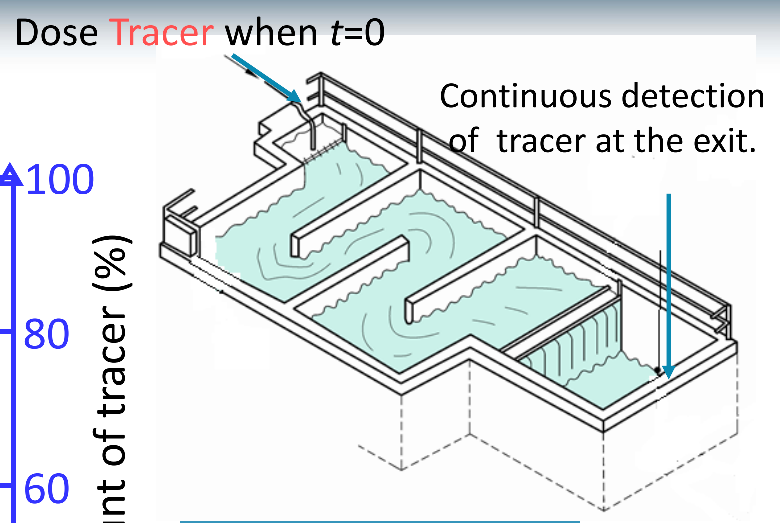
Over 90% of the water can meet the CT requirement

↓

The t_{10} should be used in verification of CT value

2. Concentration of disinfectant





Contact time t_{10}

$$t_{10} = \beta T = \beta \frac{V}{Q}$$

t_{10}: contact time that 90% water in clean-water reservoir can achieve.

β: Effective coefficient.

Good plug flow: 0.65-0.85

T: theoretical retention time of clean-water reservoir's

V: Volume of clear-water reservoir

2. Concentration of disinfectant

Improve the plug flow in clear-water reservoir.

$$t_{10} = \beta T = \beta \frac{V}{Q}$$

- Add baffles, reduce short flow

⇒ Increase β

⇒ Get higher CT value

Relation between CT and logarithmic removal of microorganisms

$$CT = -\frac{2.303}{k'} \lg \frac{N_t}{N_0}$$

For a certain species of microorganism:

$$\frac{CT_2}{CT_1} = \frac{\lg\left(\frac{N_t}{N_0}\right)_2}{\lg\left(\frac{N_t}{N_0}\right)_1}$$

- Increasing CT value:

⇒ Higher microorganism's logarithmic removal.

⇒ Higher microorganism's concentration removal.

3. Temperature

$$\lg\frac{k_2}{k_1} = \frac{E}{2.303R} \times \frac{(T_2 - T_1)}{T_1 \cdot T_2}$$ Arrhenius' formula

K_1, K_2: Inactivation rate constants under temperature T_1, T_2

R: Universal gas constant, 8.314 J/(mol K).

E: Activation energy, J/mol.

Generally:

Temperature ↑ → Disinfection rate constant ↑ → Disinfection performance ↑