Physical characteristics of water

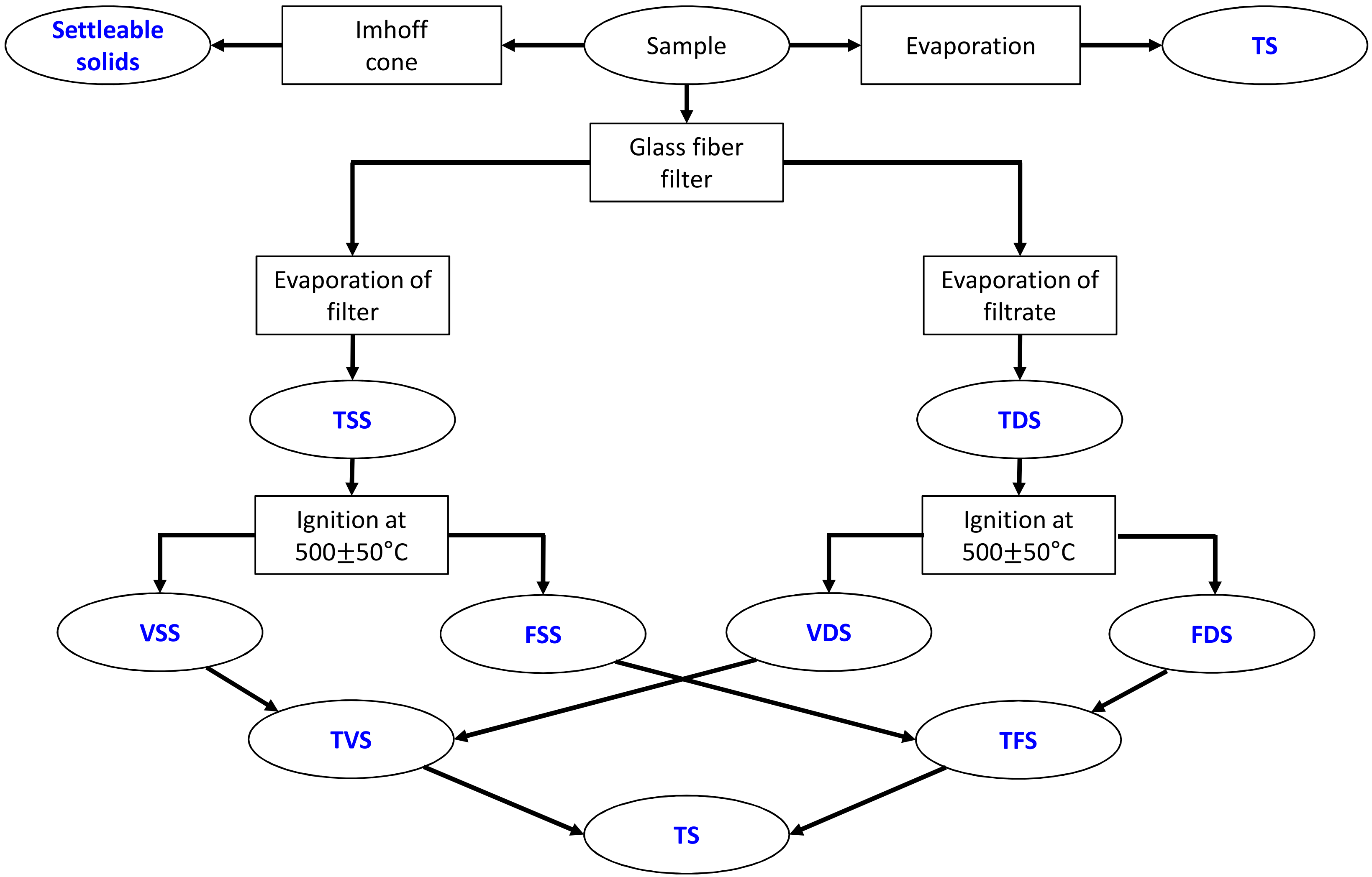
Solids

- All constituents of water other than water and dissolved gases
- **Dissolved vs. suspended**
  - Penetrates vs. retained on a filter
  - Filter with a pore size of 0.45 – 2 μm is used
- **Fixed vs. volatile**
  - Remains vs. volatilized at 500±50℃
  - Volatile solids are considered to be <u>organic</u>: used to differentiate organics and inorganics

Water constituents

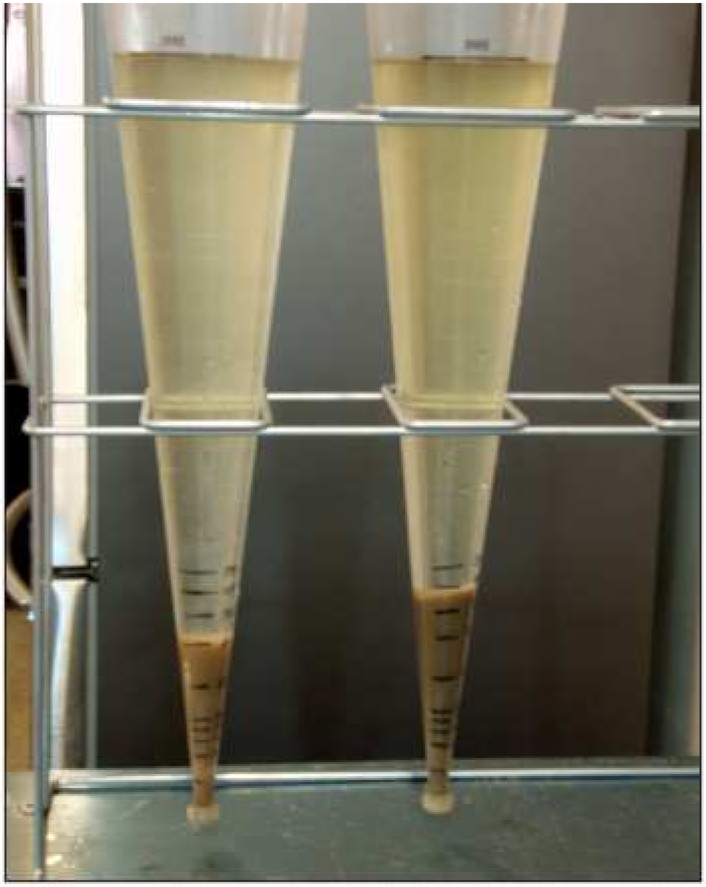
- **Suspended matter**
  - Operationally defined as the material that retained on a 0.45 µm filter
  - Colloids: 1 nm – 1 µm in size
  - Includes mineral colloids, microorganisms and their debris, organic polymers
  - Influences:
    - Contaminant transport
    - Light attenuation
    - Disinfection efficiency
    - Aquatic habitat

Solids – content analysis



Solids content analysis – settleable solids

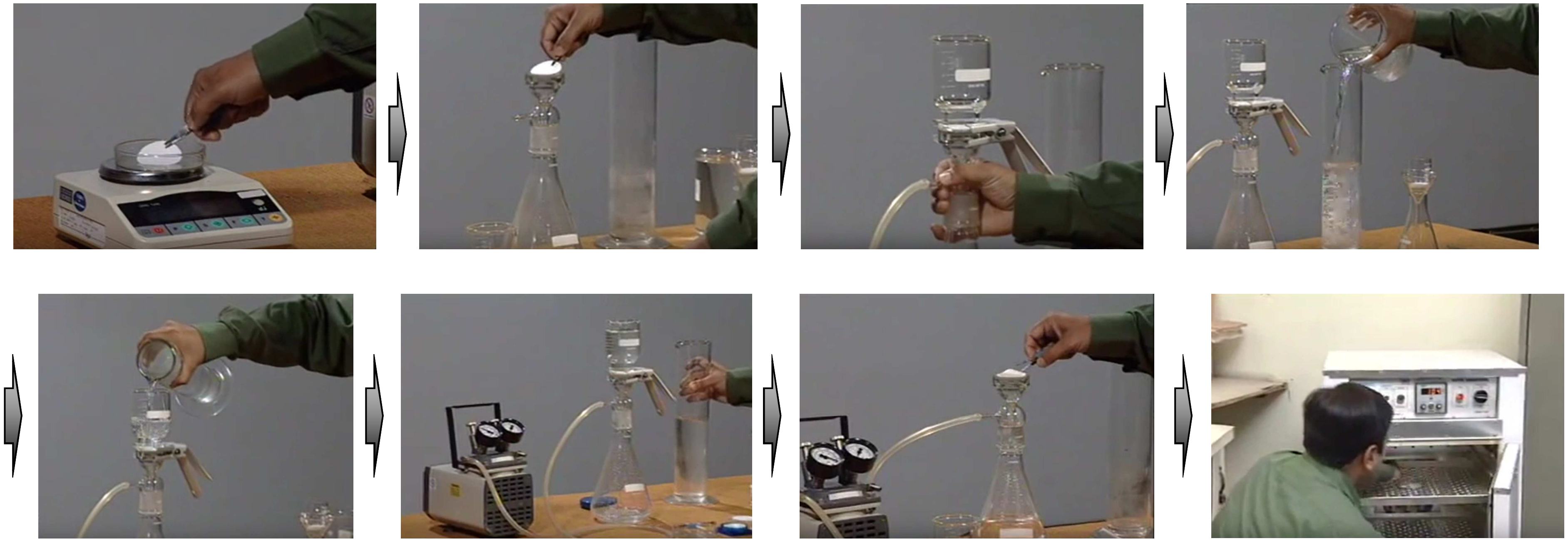
#1



Add 1L in Inhoff cone, wait for 1 hr for settling & record the volume of the thick, bottom layer (reported as mL/L)

Solids content analysis – suspended solids

#2



#3

Solids content analysis

Q: The following test results were obtained for a wastewater sample. All the tests were performance using a sample size of 50 mL. Determine the concentrations of TS, TVS, TSS, VSS, TDS, and VDS.

Mass of evaporating dish = ***53.5433 g***

Mass of evaporating dish + residue after evaporation at 105°C = ***53.5794 g***

Mass of evaporating dish + residue after ignition at 500°C = ***53.5625 g***

Mass of filter paper after drying at 105°C = ***1.5433 g***

Mass of filter paper + residue after drying at 105°C = ***1.5554 g***

Mass of filter paper + residue after ignition at 500°C = ***1.5476 g***

Solids content analysis

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$$\boldsymbol{TS} = \frac{(53.5794 - 54.5433)\ g\ \times\ 10^3\ mg/g}{0.05\ L} = 722\ mg/L$$

$$\boldsymbol{TVS} = \frac{(53.5794 - 54.5625)\ g\ \times\ 10^3\ mg/g}{0.05\ L} = 338\ mg/L$$

$$\boldsymbol{TSS} = \frac{(1.5554 - 1.5433)\ g\ \times\ 10^3\ mg/g}{0.05\ L} = 242\ mg/L$$

$$\boldsymbol{VSS} = \frac{(1.5554 - 1.5476)\ g\ \times\ 10^3\ mg/g}{0.05\ L} = 156\ mg/L$$

$$\boldsymbol{TDS} = TS - TSS = 722 - 242 = 480\ mg/L$$

$$\boldsymbol{VDS} = TDS - VSS = 338 - 156 = 182\ mg/L$$

Turbidity

- A measure of clarity of water
- Unit: nephelometric turbidity units (NTU)
- Measured by the intensity of light scattered by a water sample
- Suspended and colloidal matter increases turbidity
  - No general, direct relationship between TSS and turbidity, but at certain conditions, turbidity may be used to estimate TSS

$$TSS, mg/L \cong TSS_f \times T$$

TSS_f = conversion factor, mg TSS/L/NTU

ex: 2.3-2.4 for secondary effluent;

1.3-1.6 for secondary eff. filtered by sand filter

T = turbidity, NTU;

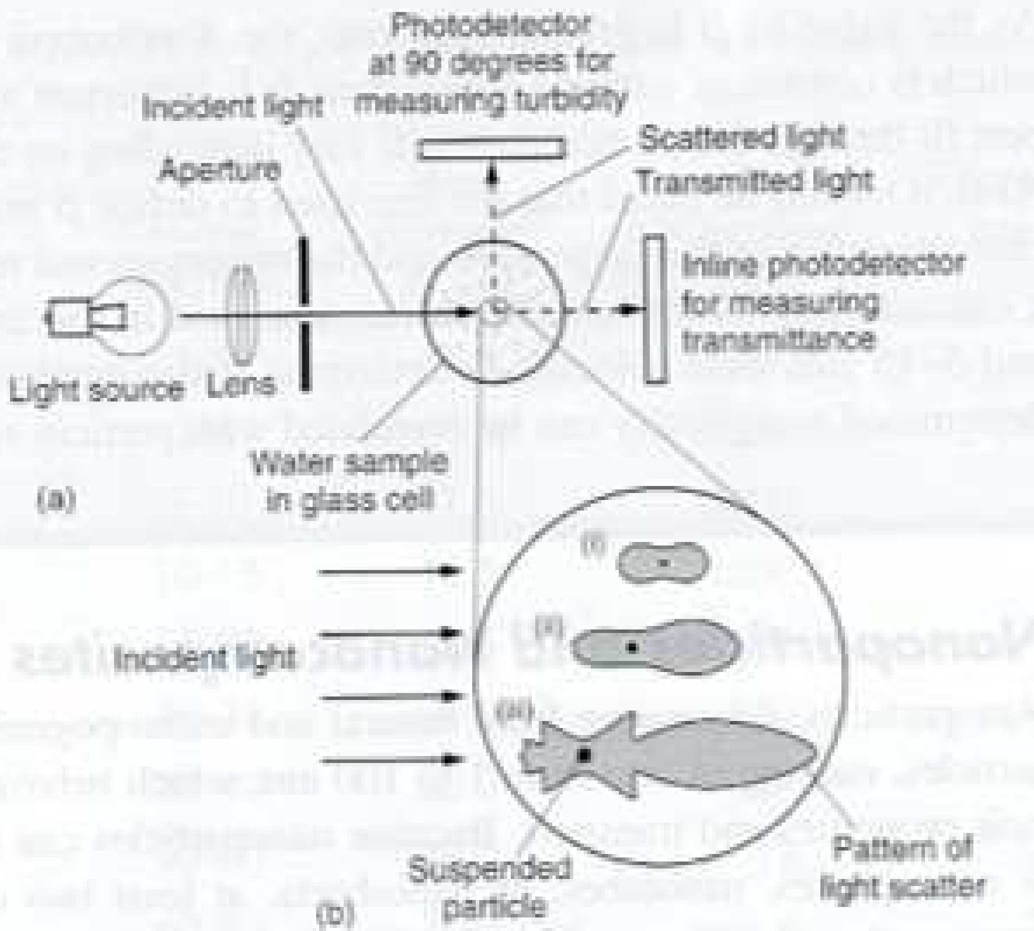
  - Turbidity can be measure real-time, on-line (TSS cannot)

Turbidity

#4

Figure 2-12

Determination of turbidity by light scattering: (a) schematic of turbidity apparatus and (b) typical light scattering patterns for small (i), intermediate (ii), and large (iii) particles.



Color

- Natural water may have yellowish color
  - Major contributor: DOM

- Fresh wastewater is in light brownish-gray color; as anaerobic condition develops, the water gets darker and eventually turn black (septic water)

#5

#6

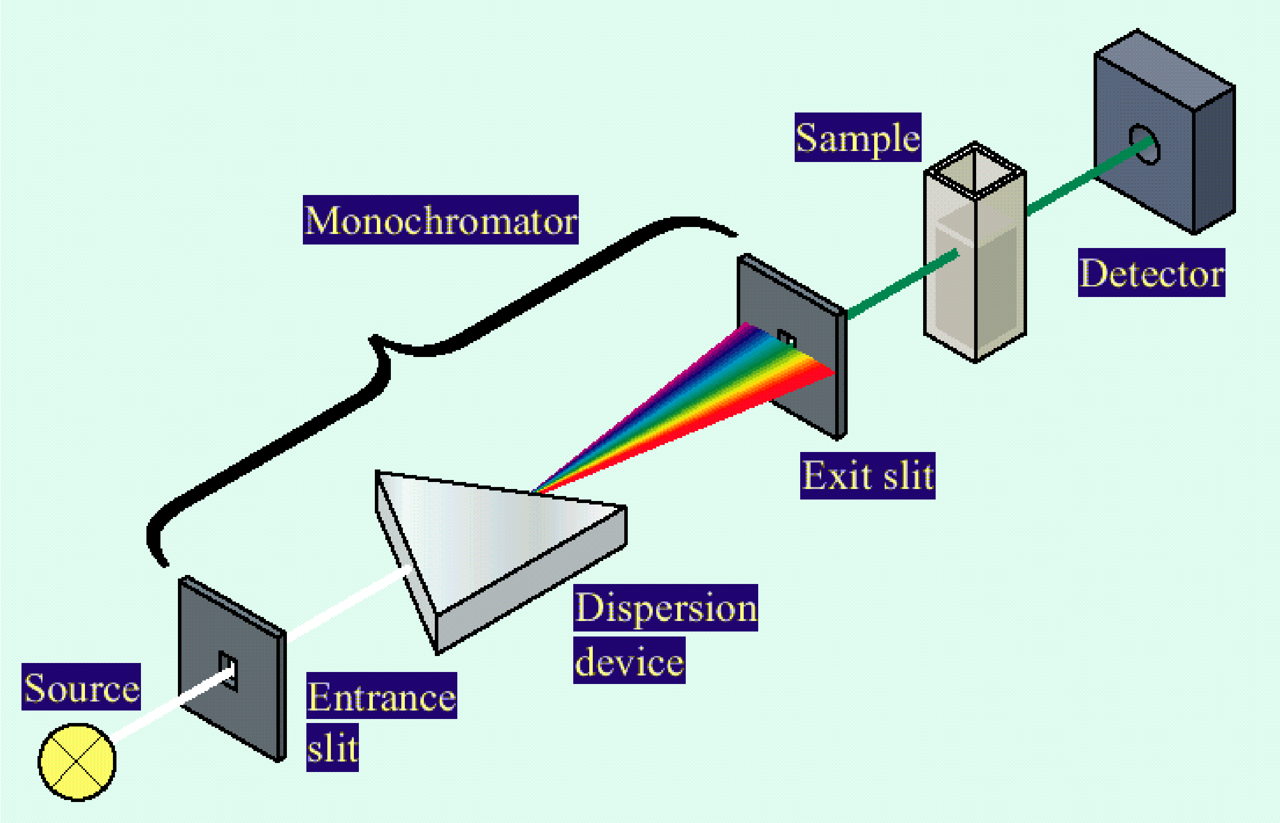
Light absorption

- **Absorbance**
  - A measure of the amount of light absorbed by the constituents in a solution
  - Typically measured at a wavelength of 254 nm using a spectrophotometer
  - Function of solute property, concentration, light path length, and light wavelength

$$A(\lambda) = log_{10}(I_0/I) = \varepsilon(\lambda)Cx$$

$A(\lambda)$ = absorbance at wavelength λ (unitless)
I_0= light intensity at light source (mW/cm^2)
I = light intensity at distance x from the light source (mW/cm^2)
$\varepsilon(\lambda)$ = molar absorptivity of the light-absorbing solute at wavelength λ (L/mole-cm)
C = concentration of light-absorbing solute (mole/L)
x = light path length (cm)

Light absorption



#7

– Absorptivity

$$k(\lambda) = \frac{A(\lambda)}{x} = \varepsilon(\lambda)C$$

$k(\lambda)$ = absorptivity (cm^{-1})

Odor

- Offensive odor usually occur in anaerobic conditions
- Most commonly reported as “Minimum Detectable Threshold Odor Concentration (MDTOC)”
- Quite subjective property

Odorous compounds in water

Odorous compound	Chemical formula	Odor quality
Amines	CH_3NH_2, $(CH_3)_3NH_2$	Fishy
Ammonia	NH_3	Ammoniacal
Diamines	$NH_2(CH_2)_4NH_2$, $NH_2(CH_2)_5NH_2$	Decayed flesh
Hydrogen sulfide	H_2S	Rotten eggs
Mercaptans	CH_3SH, $CH_3(CH_2)SH$, $(CH_3)_3CSH$, $CH_3(CH_2)_3SH$	Decayed cabbage or skunk
Organic sulfides	$(CH_3)_2S$, $(C_6H_5)_2S$	Rotten cabbage
Skatole	C_9H_9N	Fecal matter

Odor

- MDTOC determination example

mL sample	mL pure water	Odor
100 mL	0 mL	Present
50 mL	50 mL	Present
25 mL	75 mL	Barely detectable
10 mL	90 mL	Absent

$$MDTOC = 100\ mL\ /\ 25\ mL = 4$$

Temperature

- Chemical and biochemical reaction rates increase with temperature
  - van't Hoff-Arrhenius relationship

$$\frac{d(\ln k)}{dT} = \frac{E}{RT^2}$$

k = reaction rate constant

T = temperature (K)

E = activation energy (J/mole)

R = ideal gas constant (8.314 J/mole-K)

  - Modification of van't Hoff-Arrhenius relationship

    For a practical range of water temperature, $E/RT^2 \approx constant$

$$\frac{k_2}{k_1} = \theta^{(T_2 - T_1)}$$

k_1 = reaction rate at T_1

k_2 = reaction rate at T_2

θ = temperature coefficient

van't Hoff-Arrhenius when $E/RT^2 \approx$ const.

$$d(\ln k) = \frac{E}{R} \cdot \frac{dT}{T^2}$$

$$\int_{lnk_1}^{lnk_2} d(\ln k) = \frac{E}{R} \int_{T_1}^{T_2} \frac{dT}{T^2}$$

$$lnk_2 - lnk_1 = \frac{E}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\frac{k_2}{k_1} = exp\left[\frac{E}{RT_1T_2}(T_2 - T_1)\right]$$

$$let \quad \theta = exp\left(\frac{E}{RT_1T_2}\right)$$

$$\frac{k_2}{k_1} = \theta^{(T_2 - T_1)}$$

Temperature

- Gas solubility decrease with temperature

  ex) saturated dissolved oxygen DO: 13.1 mg/L @ 4℃, 9.1 mg/L @ 20℃, 7.5 mg/L @ 30℃
- Most organisms have distinct temperature ranges within which they reproduce and compete
- Slightly higher temp. in domestic wastewater and much higher temp. in cooling water → can damage aquatic ecosystem
  - Low saturation DO, faster oxygen consumption rate by microorganisms → DO depletion
  - Direct effect of temperature increase on aquatic organisms
- Heat recovery from wastewater of current interest

References

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