

Physical characteristics of water

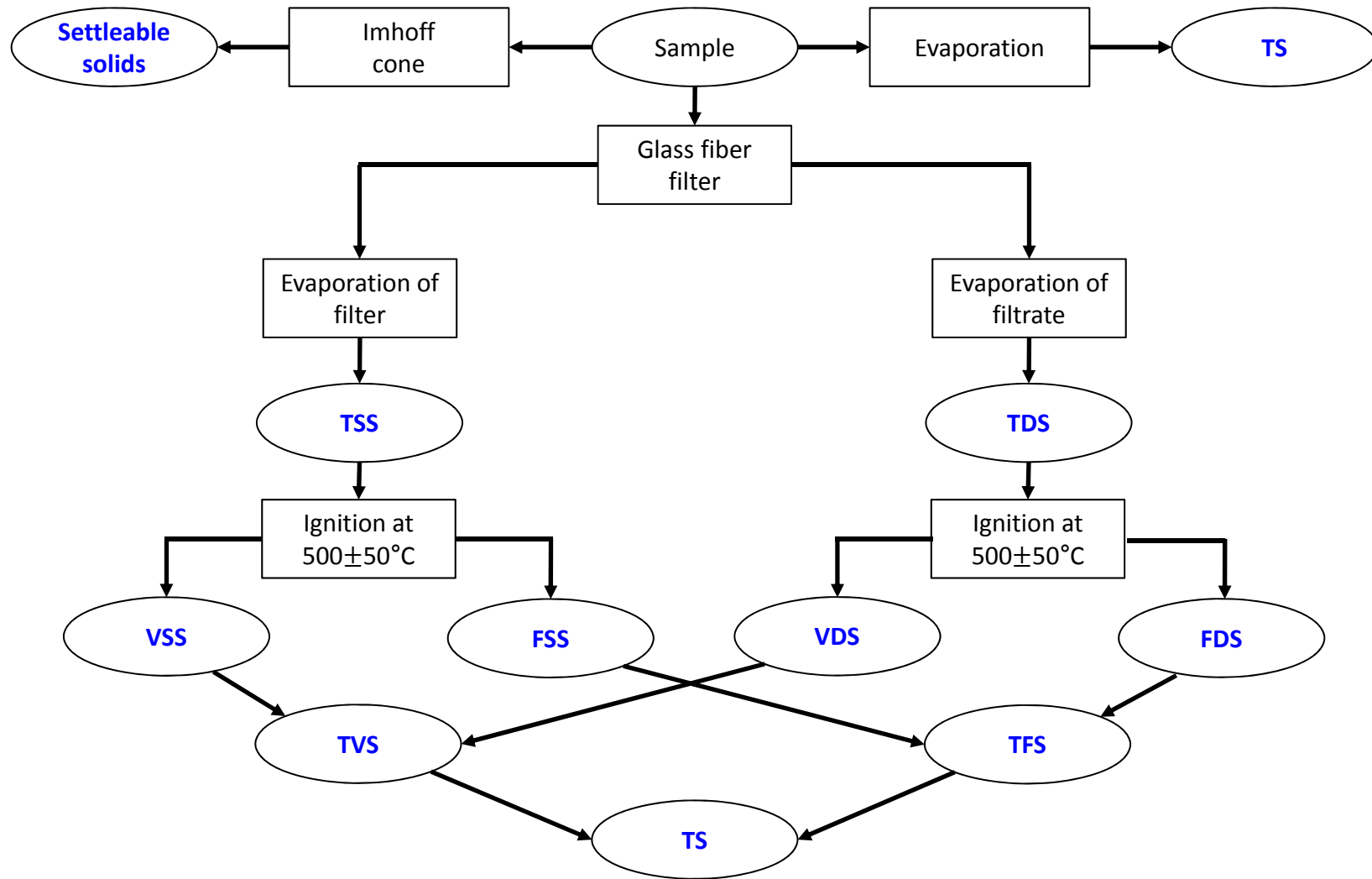
Solids

- 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 $500 \pm 50^\circ\text{C}$
 - Volatile solids are considered to be organic: 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



Imhoff cone used for settleable solids analysis

<http://interagua.pt>

*Settleable solids determination:
Add 1L in Imhoff cone, wait for 1 hr for settling & record the volume of the thick, bottom layer (reported as mL/L)*



Filter paper & filter assembly used for suspended solids analysis

<http://ian.umces.edu>

<http://fishersci.com>

<https://www.indiamart.com>

Solids content analysis

Q: The following test results were obtained for a wastewater sample. All the tests were performed 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***

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

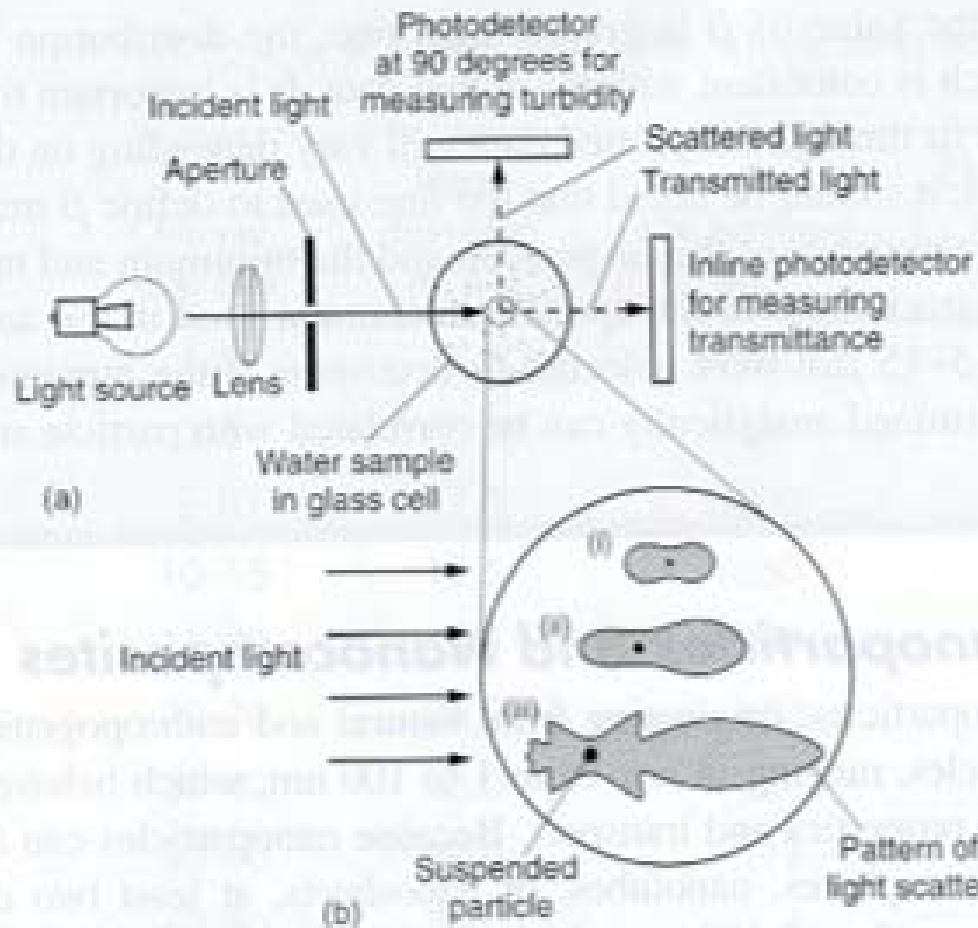
T = turbidity, NTU;

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

Turbidity

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)



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(λ) = absorbance at wavelength λ (unitless)

I₀ = light intensity at light source (mW/cm²)

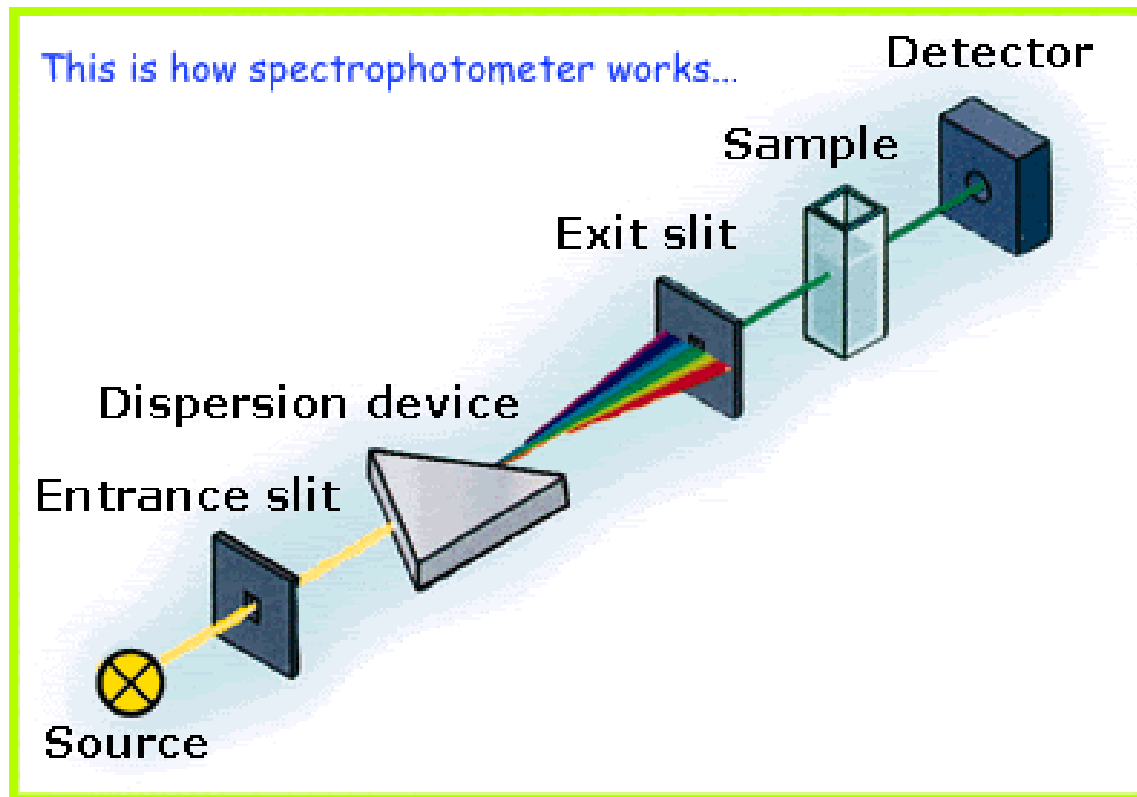
I = light intensity at distance x from the light source (mW/cm²)

ε(λ) = 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



<http://allcars.pw>

– 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	$\text{CH}_3\text{NH}_2, (\text{CH}_3)_3\text{H}$	Fishy
Ammonia	NH_3	Ammoniacal
Diamines	$\text{NH}_2(\text{CH}_2)_4\text{NH}_2, \text{NH}_2(\text{CH}_2)_5\text{NH}_2$	Decayed flesh
Hydrogen sulfide	H_2S	Rotten eggs
Mercaptans	$\text{CH}_3\text{SH}, \text{CH}_3(\text{CH}_2)\text{SH}, (\text{CH}_3)_3\text{CSH}, \text{CH}_3(\text{CH}_2)_3\text{SH}$	Decayed cabbage or skunk
Organic sulfides	$(\text{CH}_3)_2\text{S}, (\text{C}_6\text{H}_5)_2\text{S}$	Rotten cabbage
Skatole	$\text{C}_9\text{H}_9\text{N}$	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	<u>Barely detectable</u>
10 mL	90 mL	Absent

$$MDTOC = 100 \text{ mL} / 25 \text{ mL} = 4$$

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, $E/RT^2 \approx \text{constant}$

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

*k*₁ = reaction rate at *T*₁

*k*₂ = reaction rate at *T*₂

θ = temperature coefficient

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

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

$$\int_{\ln k_1}^{\ln k_2} d(\ln k) = \frac{E}{R} \int_{T_1}^{T_2} \frac{dT}{T^2}$$

$$\ln k_2 - \ln k_1 = \frac{E}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\frac{k_2}{k_1} = \exp \left[\frac{E}{RT_1 T_2} (T_2 - T_1) \right]$$

$$\text{let } \theta = \exp \left(\frac{E}{RT_1 T_2} \right)$$

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

Temperature

- Gas solubility decrease with temperature
 - ex) saturated dissolved oxygen DO: 13.1 mg/L @ 4°C, 9.1 mg/L @ 20°C, 7.5 mg/L @ 30°C
- 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