Physical characteristics of water

Today's class

- Solids content
- Turbidity, color, light absorption
- Taste and odor
- Temperature

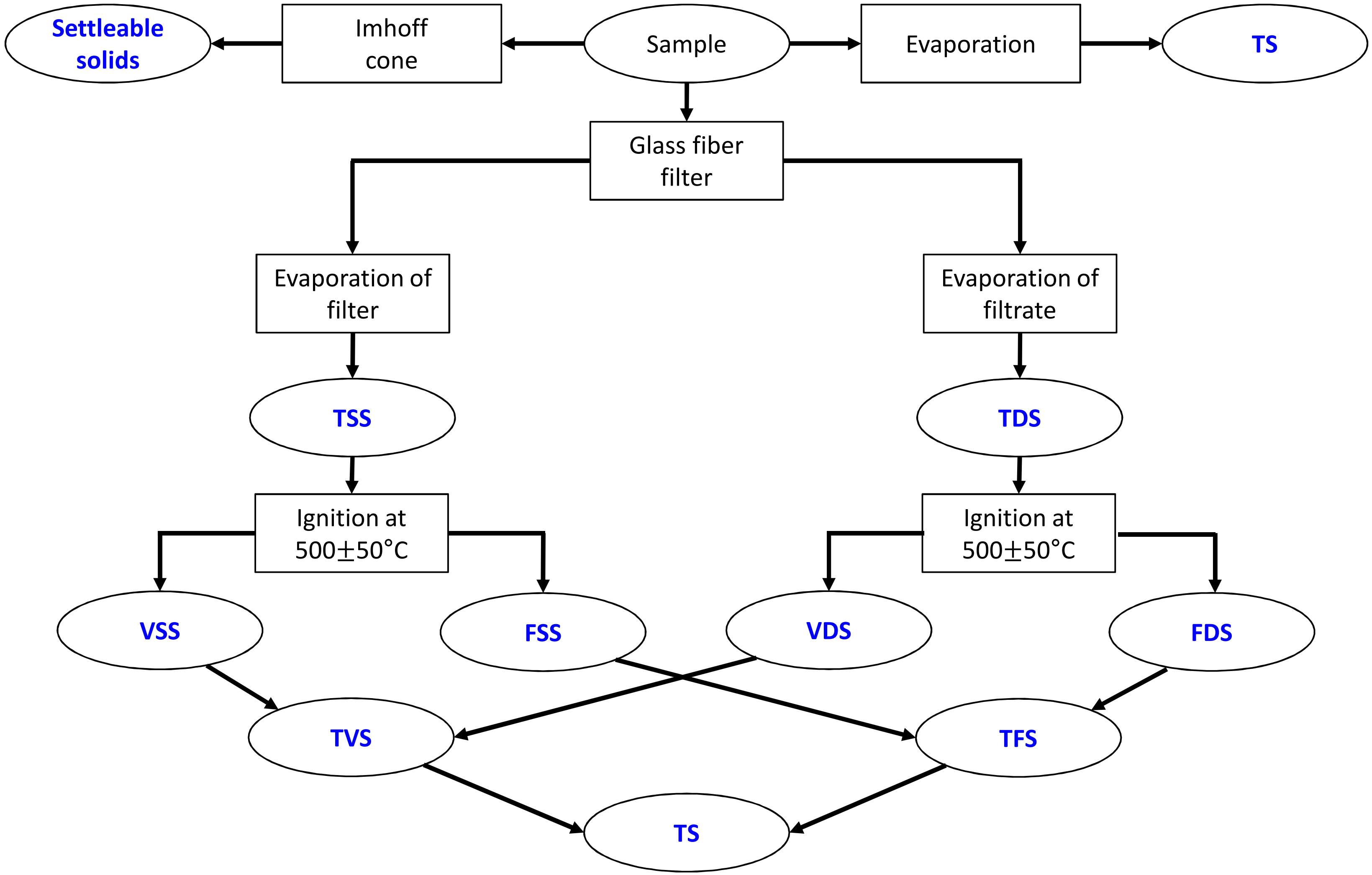
Solids

- 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 organic: used to differentiate organics and inorganics

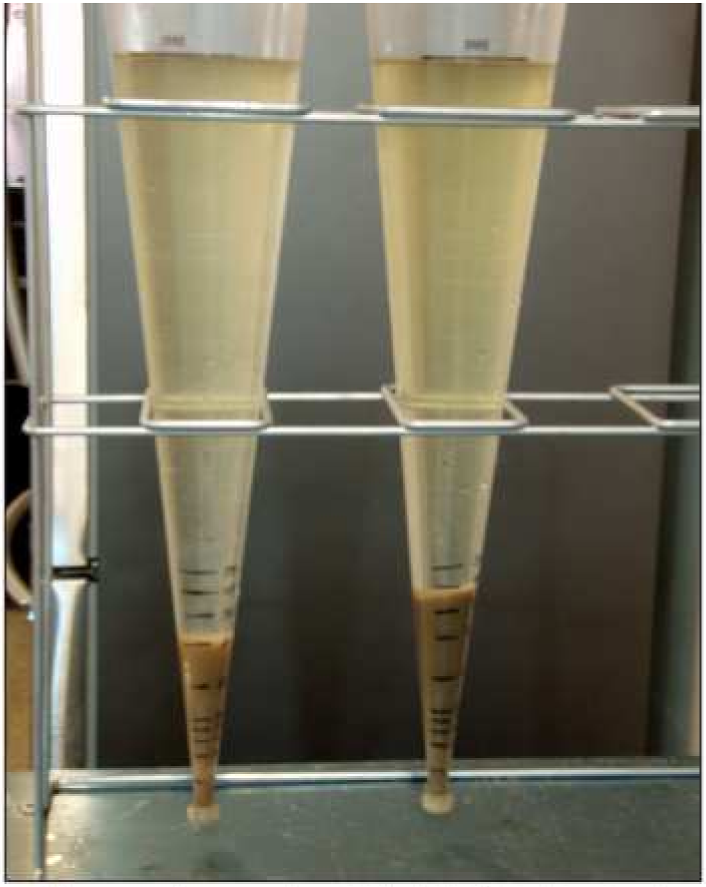
Water constituents

- **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

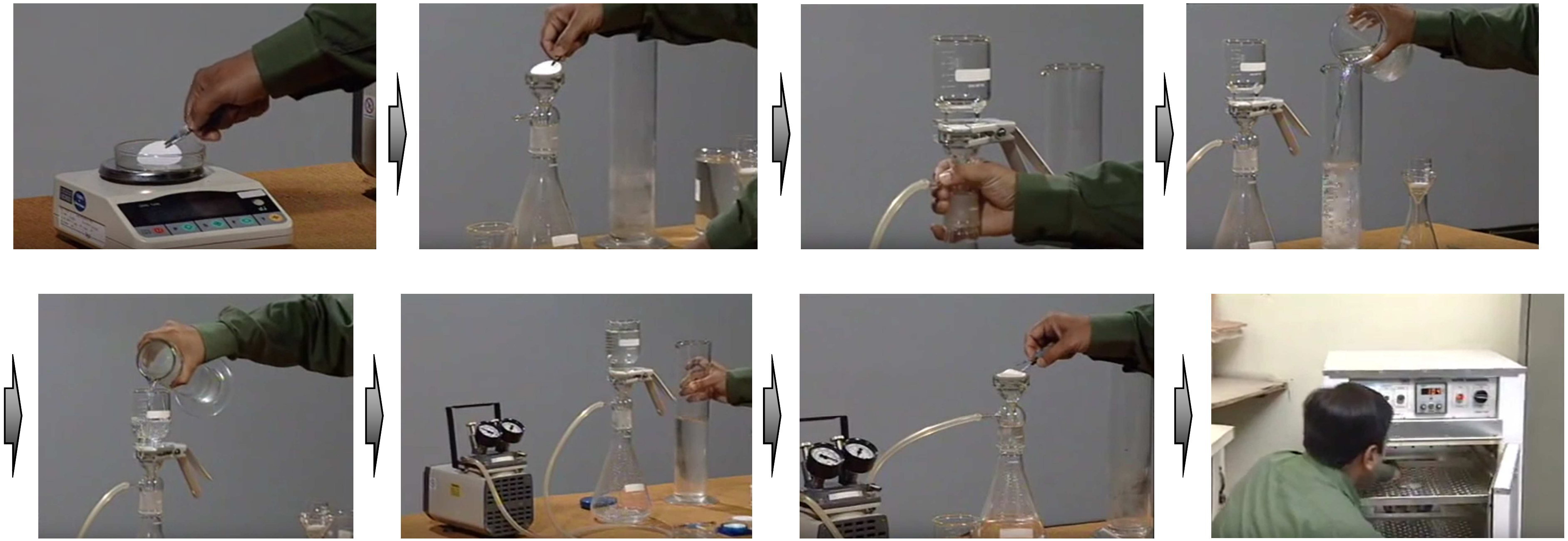


Solids content analysis – settleable solids



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



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

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

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

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

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

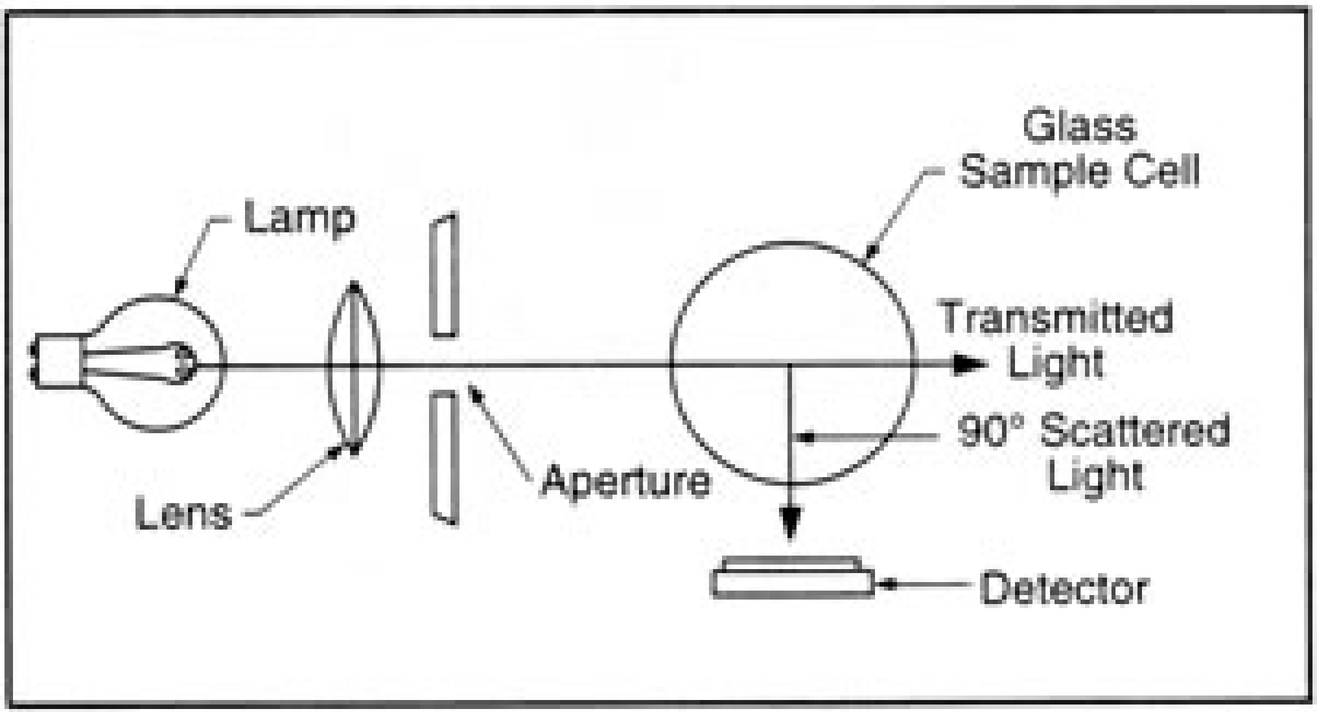
$$\boldsymbol{VDS} = \ TDS - VSS = 338 - 156 = 182\ mg/L$$

Color

- Natural water may have yellowish color
  - Major contributor: dissolved organic matter (DOM)
- Fresh wastewater is in light brownish-gray color; as anaerobic condition develops, the water gets darker and eventually turn black (septic water)
  - Black color due to formation of metal sulfides (ex: FeS)

Turbidity

- A measure of clarity of water
- Measured by the intensity of light scattered by a water sample



Turbidity

- Unit: nephelometric turbidity units (NTU)
- 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 (cf. TSS cannot)

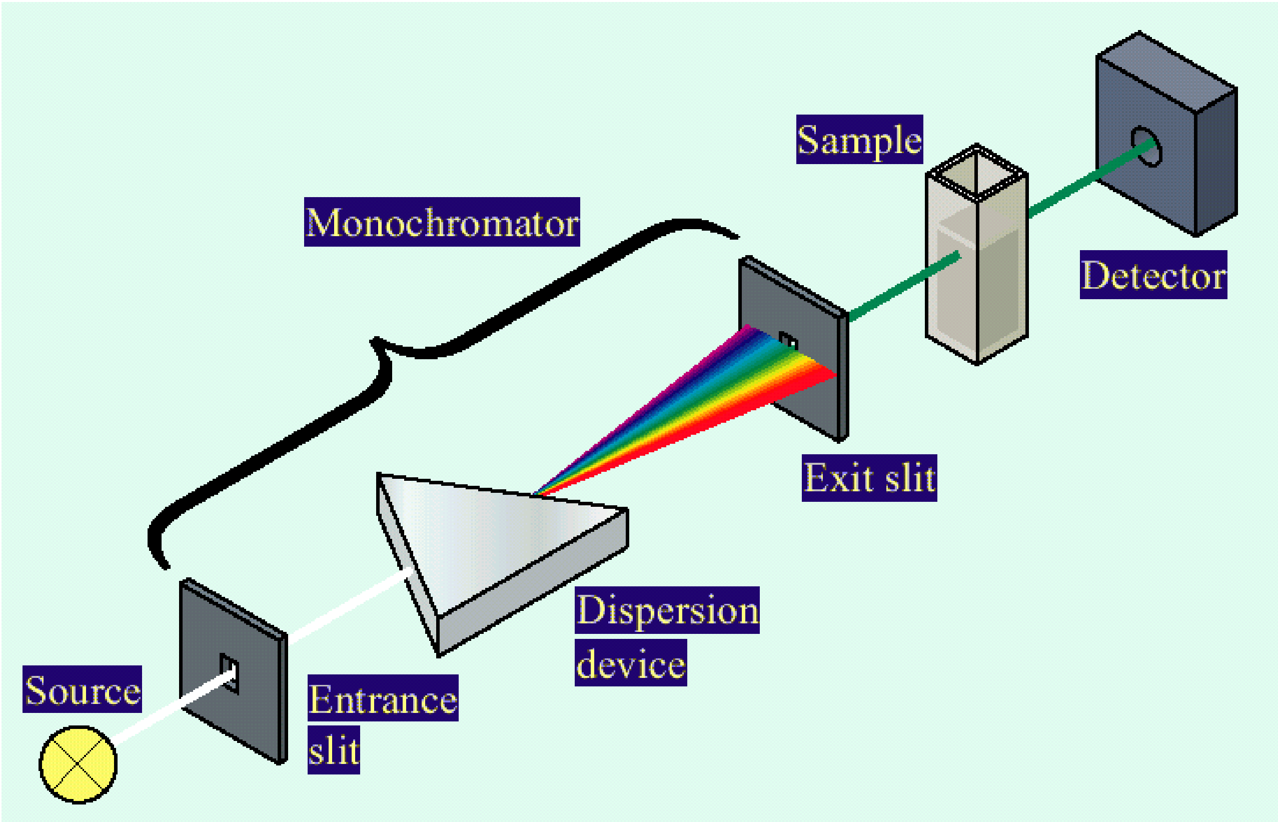
Light absorption

- **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



– Absorptivity

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

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

Taste and odor

- Quite subjective property
- Use blind testing

물 맛·냄새 감별법으로 '맛있는 물' 만든다

천윤정 기자 | kularz@hellodd.com | 입력 2007.06.04 10:19 | 댓글 0

수공, 30명 패널 훈련 최종 '맛' 테스트로 완벽 기해

마트에 가보면 스위스 청정 암반에서 추출했다는 물에서부터 불소와 칼슘이 많이 들어 있어 끓이지 않고도 분유를 탈 수 있다는 일본 유아용 물까지 생수의 등급과 종류가 가지각색이다. 1ℓ당 1만원에 가까운 가격에도 불구하고 몸에 좋고 맛도 색다르다는 소문에 '불티나게' 팔리고 있는 생수도 있다. 현재 국내 생수시장 규모는 3천500억원에 달하고 있으며 최근에는 메뉴판에 오직 물만 적혀있는 '물 카페'가 등장할 정도로 생수는 수돗물과는 비교할 수 없는 신뢰를 얻고 있다. 그런데 정말 수돗물은 생수보다 못한 걸까?

수돗물의 '누명'? "친구들이 저에게 수돗물을 마시냐고 묻죠. 저 뿐 아니라 여기 직원들 모두 수돗물을 먹고 있습니다. 마셔보면 물 맛도 좋고 냄새도 나지 않습니다." 대전 수자원공사 수돗물분석연구센터에 근무하는 방석배 수질연구실 과장은 사람들의 수돗물에 대한 거부감과 편견에 대해 안타까워하며 말했다. 실제 수공 뿐 아니라 정부과천청사 장관실에 공급하는 페트(PET)병 물도 생수가 아니다. 한국수자원공사 대청댐 청주 정수장에서 생산한 'K-WATER'다. 여의도 벚꽃 축제장, 하이서울 페스티벌에서 나눠준 물 역시 청주 정수장 물이었다. 하지만 왜 사람들은 수돗물에 대해 그토록 불신하고 있는 것일까? 우리나라

Odor

- Offensive odor usually occur in anaerobic conditions
- Can be reported as "Threshold Odor Concentration (TOC)"

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

- TOC 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

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

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≈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

Key references

- Textbook sec 2-3, 2-4

Next class

- Chemical characteristics of water I
  - Dissolved ions
  - Macronutrients: N, P, S
  - pH and EC
  - Alkalinity, hardness, and sodium adsorption ratio